COMBUSTION

Vol. I, No. 7 JANUARY 1930

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The Selection of Stoker Drives
By T. A. PEEBLES

Phosphate Treatment of Boiler Water
By EDWARD P. PRICE

Other Articles in This Issue by
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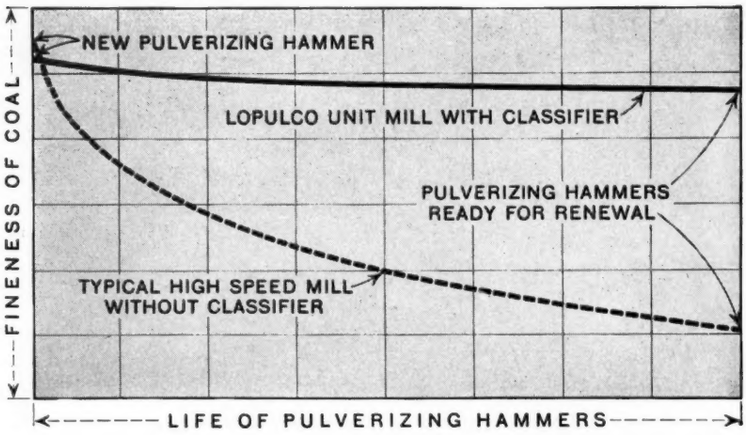
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COMBUSTION

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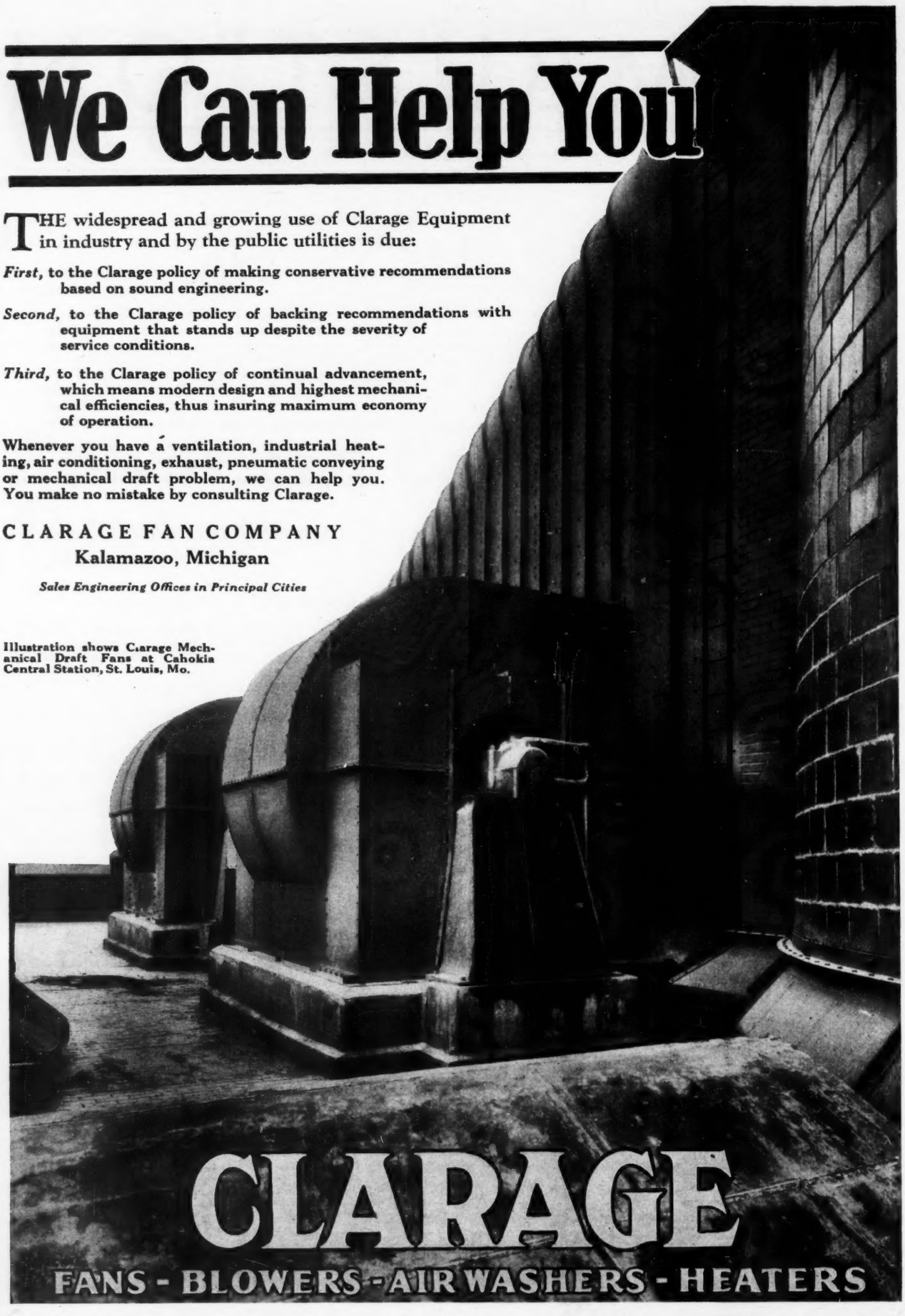

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COMBUSTION

Vol. 1 January 1930 No. 7

The Public Utility Outlook for 1930

Photo by Blank-Stoller, Inc.

PAUL S. CLAPP

ELECTRIC light and power development has made good progress during the year. The outlook for the new year is bright. During 1929, output of electricity increased by 10 per cent to a record total of 97½ billion kilowatt-hours. During 1930, electrical output will reach 100 billion units.

Electrical energy used by factories, mines and quarries grew by nearly 12 per cent, reflecting the increased dependence of industrial enterprises upon the electric light and power companies for power supply. Three-fourths of the country's manufacturing establishments are now electrified with two out of every three horsepower of motors operated on energy supplied by electric utility companies.

To an increasing degree, major dependence in electric power production continues to be from fuel-burning plants. This year, electric generating capacity increased by 2,400,000 horsepower—90 per cent of which was in fuel-burning plants and only 10 per cent hydro-electric. Shortage of water in many sections of the country, together with increased demands for power because of unusual industrial activity required heavier electric output from steam-generating plants. Production of hydro-electric energy decreased over the total of the previous year, while steam-generated electricity increased by nearly 18 per cent.

Marked gains in efficiency of steam plants continue with higher pressures and temperatures, and concentration of production in continuously larger units. The average quantity of coal needed to produce a kilowatt-hour reached 1.66 pounds this year, or about one-half of that required ten years ago.

The electric power companies plan to spend $865,000,000 during 1930 for new construction, improvements and extension of facilities. This is a gain of $65,000,000 over similar expenditures during 1929. Nearly 20 per cent, or $175,000,000, will go toward steam plant construction. In addition, $125,000,000 will be spent for the upkeep and maintenance of existing facilities. These plans have already been formulated and orders for much of the equipment and material have been placed.

Paul S. Clapp

Managing Director,
NATIONAL ELECTRIC LIGHT ASSOCIATION

EDITORIAL

Co-operation Between Plant Engineers and Equipment Manufacturers

PROGRESS in the development of steam plant equipment is essentially cooperative, in that the manufacturer can only succeed in applying new ideas and improved designs through the willingness of plant operators to adopt them. The plant operator has the right to expect that the manufacturer will check, in every way possible, the theoretical values and practicability of new and untried designs, but he must realize that the only conclusive test is the final result secured in actual operation under typical-conditions of service. For this test, the manufacturer must inevitably look to the plant engineer.

This situation has been quite apparent in connection with the major developments which have occurred in the steam plant field during the past ten or twelve years. Pulverized fuel, improvements in stokers, furnace design and boilers, and, more recently, the adoption of high pressures, are all developments which have succeeded because of the willingness of plant operators to try them out and to assume the incidental responsibilities.

The plant engineer must go farther than merely expressing a personal willingness to try out new equipment. Generally he has a greater technical appreciation of the merits of the design offered than his superiors, whose approval of the expenditure is required, and he must use the confidence which his superiors repose in him to assist in securing their approval. Doing this is part of his job because it is his responsibility to take advantage of any improved method or device that will contribute to better and more economical operation. He also has a personal incentive for those who are identified with progressive work will benefit by the recognition it receives.

Of course, the manufacturer's responsibility does not cease with the installation of equipment, irrespective of whether it represents a radical departure from standard practice or conforms closely to it. This conception of the service idea is adhered to today by practically all of the leading equipment manufacturers, and, in this fact, there is definite assurance to the operating engineer that he will receive complete cooperation in overcoming the troubles, generally of a minor nature, which attend the first commercial applications of new designs.

Many specific examples could be cited of the results secured through this form of cooperation. An editorial in the December issue of COMBUSTION enumerated a whole sequence of important developments which were traceable to the initial application of pulverized fuel firing to steam boilers at the Oneida Street Station, Milwaukee. Such instances of individual courage and willingness to assume a share of the responsibility are undoubtedly a part of the history of every major development in the engineering field.

The benefits to be derived from such cooperation should inspire operating engineers to give earnest and helpful consideration to new developments initiated by responsible equipment manufacturers. The progress of the future is largely dependent upon a continuance of this attitude of mutual confidence and cooperation.

Feedwater Treatment

AN authority on this subject recently said that the State should attach as much importance to the treatment of boiler feedwater as it does to the condition of the boiler itself. State laws provide that boilers be inspected regularly to assure the safety of their operation, but there are no restrictions with regard to the suitability of raw water, used for boiler make-up, which, if it is not properly prepared, may be the cause of serious accidents. There are some circumstances that might make it impractical to enforce regulation along this line, but the idea merits consideration and it serves to emphasize the importance of the subject.

The present day trends toward larger units and higher steam pressures and temperatures have brought about conditions which have made this situation more acute. However, in the larger plants, feedwater treatment of some kind has become more or less customary and in such plants the question resolves itself into a selection of a particular type of treatment. On this score, there is considerable difference of opinion, but nevertheless progress is being made in the matter of proper adaptation of treatment to the operating conditions and the characteristics of the raw water available.

COMBUSTION recognizes the current importance of this subject by publishing two articles in this issue, one presenting the various methods of feed water treatment used abroad, and the other telling of experiments conducted for the past two and a half years in a large American plant. The latter article is of very practical value because the experiments are recorded in some detail and provide a basis for some very interesting conclusions. Both articles are worthy additions to the rapidly growing bibliography of the subject.

Forced draft, chain grate stoker driven by adjustable speed d.c. motor, providing, in this particular installation, a speed range on the grate of 15 to 60 ft. per hr. Double worm reduction gearing transmits power from low speed worm wheel to stoker shaft through a pair of spur gears.

The Selection *of* Stoker Drives

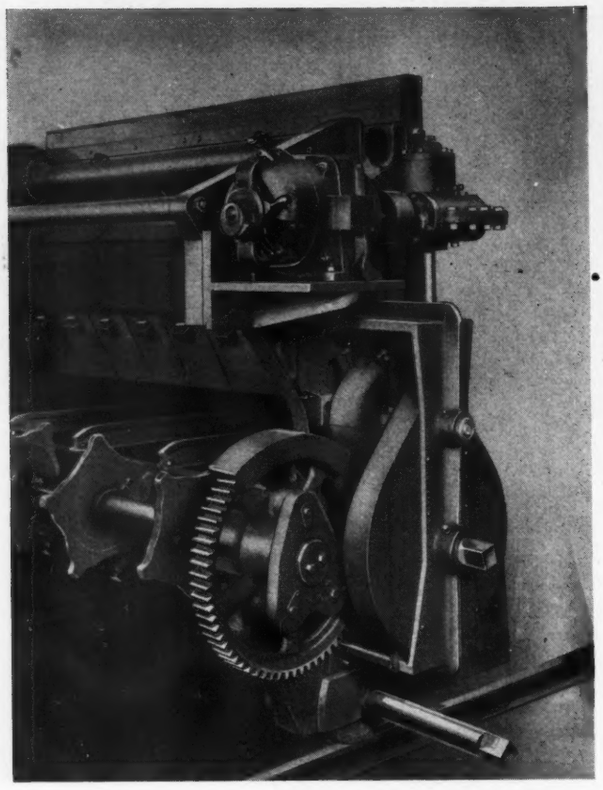
By T. A. Peebles
Hagan Corporation, Pittsburgh

At different times and in different localities a variety of reasons have influenced the installation of mechanical stokers. In some cases the elimination of smoke has been the controlling factor; in others a reduction in labor costs or the ability to burn a fuel that could be secured at an attractive price has determined the selection. In every case, however, the features, built into the mechanical stoker, by means of which it is possible to improve the efficiency of combustion, have been given consideration and the history of stoker development may be reviewed by outlining the developments that have resulted in gradually increasing the efficiency of combustion.

Increasing the efficiency of combustion has been the objective toward which all major improvements in the design of stokers have been aimed. This premise, stated by the author, which is easily proved from an economic standpoint, leads naturally to the conclusion that stoker drives should be selected primarily on the basis of their ability to provide the speed range required to operate the stoker at the highest combustion efficiencies. The various types of stoker drive now in use are carefully analyzed and their advantages and limitations discussed.

The modern stoker is a highly developed piece of equipment for the performance of certain functions, but it is not possible to credit it with certain definite characteristics such as might be ascribed to a motor or a steam turbine. The motor or turbine will give certain performance under a given set of conditions whereas the stoker will reach a specified standard of performance only when given continuous and intelligent supervision. While it is not proper to state that the motor or turbine will give results independent of the supervision which they receive, they are much less dependent upon this supervision than the mechanical stoker.

In the operation of a mechanical stoker, fuel and air must be introduced in the proper proportions to permit of efficient combustion of the fuel, and the rate of supply must be in proportion to the work the stoker is called upon to do. The mere introduction of the proper relative quantities of fuel and air does not, however, insure satisfactory conditions of combustion. The method of introduction must be such that proper contact between fuel and air is secured. It is, therefore, necessary that a layer of burning fuel must overlie the portions of the stoker through



Natural draft, chain grate stoker driven by d.c. adjustable speed motor through double reduction worm gearing and a set of spur gears

which air is admitted. Any lack in uniformity of the fuel bed has an adverse effect on the efficiency of combustion.

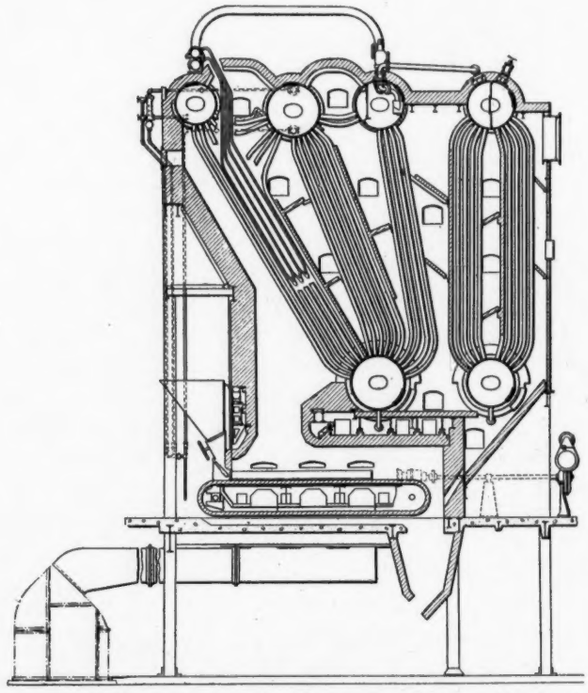
The average stoker when in operation contains a large amount of fuel in various stages of combustion which provides a reserve of fuel, and it is not necessary that at each instant there be a rate of fuel supply corresponding to the rate of combustion. On the other hand the air supply must be proportional to the rate of combustion, because for a fuel bed in proper condition, the rate of combustion at any instant is determined by the rate of air supply. The air supply must, therefore, vary with the load on the stoker and in synchronism with load variations. While it is only necessary to regulate the rate of fuel supply so as to maintain the fuel bed in a proper condition, evidently this condition would be best maintained if at all times the rate of fuel supply could be made to bear the proper relation to the rate of combustion.

The feeding mechanism of a mechanical stoker can hardly be called a coal meter, or more precisely a B.t.u. meter. For any given rate of operation of the fuel feeding mechanism, the rate at which B.t.u.'s are delivered to the furnace will vary with the heating value of the coal, its moisture content, and its physical condition as to fineness and moisture content, both of which affect the pounds of fuel that will be supplied to the furnace in a unit of time. In spite of these variable conditions it is still desirable as one of the primary steps in securing good combustion, that the rate of operation of the fuel feeding mechanism be maintained in proportion to the load on the stoker.

In the selection of a stoker drive, it is important to consider how closely each method of drive under consideration will meet the requirement of regulating the speed of the stoker in accordance with the load variations. Twenty years ago the steam engine was used almost exclusively for stoker drive. It is capable of wide variations in speed, and this speed can be varied by very small increments provided a suitable speed regulating valve is available. This method of drive failed to meet the requirements of modern stations for two reasons:

(1) It is now generally recognized that each stoker should have its own individual drive or speed changing device, but a multiplicity of small steam engines operating on high pressure superheated steam, introduces a number of undesirable operating difficulties.

(2) The heat balance of the station often does not permit of the use of high pressure steam by noncondensing units.

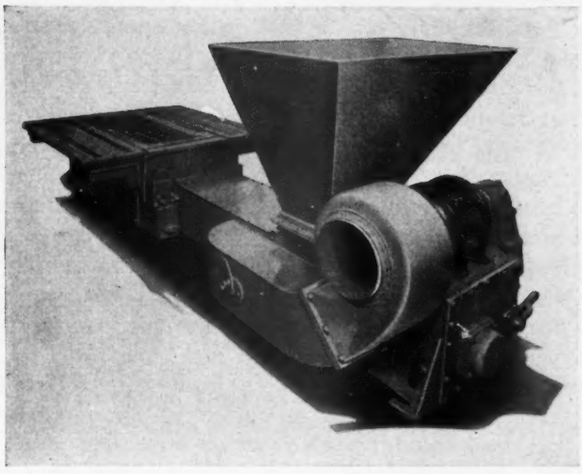


Forced draft, traveling grate stoker driven by adjustable speed d.c. motor with speed range of 450 to 1800 r.p.m. Power is transmitted through double worm reduction gearing

The engineer in designing a modern station, has four methods of drive from which to make his selection:

(1) Variable speed a.c. motor
(2) Constant speed a.c. motor with variable speed transmission
(3) Variable speed d.c. motor
(4) Steam turbine

The wound rotor type of motor is suitable where



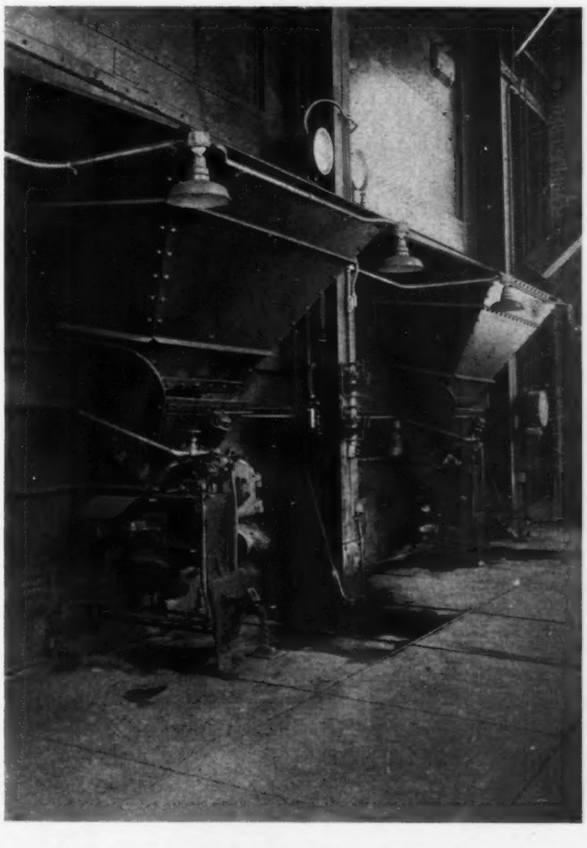
Small unit-type stoker driven by constant speed a.c. motor. Variation of coal feed is secured by means of pawl and ratchet mechanism

the required speed range does not exceed two to one. This speed range is sufficient in many plants where extreme load variations do not occur, and where a two to one range of stoker speed is sufficient to meet the load variations which will be imposed on any one boiler. The characteristics of this type of motor make it an inadequate type of stoker drive where a speed range of more than two to one is required. A greater speed range can be secured by utilizing a two speed stoker drive, but this somewhat complicates the operator's work if he attempts to maintain a stoker speed proportional to the load. Where this method of drive must be employed there should always be an indicating tachometer operating from the stoker shaft to show the operator the exact speed at which the stoker is operating.

The four speed motor has been used in some cases but it is difficult to see how this type of motor can even approximately meet the required conditions. With a load that may, at any given time, lie anywhere between the minimum and the maximum, the operator is confronted with the task of maintaining the fuel bed in the right condition with a stoker drive capable of only four separate speeds. If the existing load called for a stoker speed about midway between two of the four motor speeds available, he would be required to operate alternately at rates of fuel supply considerably above and below the correct rate. It requires an unusual amount of skill and very close supervision of the stoker operation to maintain the proper fuel bed conditions with a combination of this sort, and since, in the last analysis, efficiency of combustion depends largely on the condition of the fuel bed, the best results are not to be expected with this type of drive. The use of the four speed motor with a two speed gear box increases the total range of operation but does not materially simplify the problem of securing a stoker speed proportional to the load.

The constant speed motor has simplicity and reliability to recommend it, and, with a simple and compact speed changing device, makes a very desirable stoker drive. This combination has not come into general use possibly because a variable speed drive designed particularly for this service is not available. It would appear that with variable speed drives widely used in other classes of service there will be further developments along this line. Such development should result in a drive having all the required characteristics of wide range and speed adjustment through small increments.

The direct current shunt-wound motor has favorable characteristics. It can be secured to give a four to one speed range with small increments throughout this range. Variations in torque cause practically no change in speed and the increased torque of the stoker drive with decreased speed has practically no effect on the regulation. The use of d.c. current for power station auxiliaries has decreased within recent years and special provision is often necessary to provide a dependable source of d.c. power for stoker drive. This has often prevented its use and has resulted in



Single retort, underfeed stoker driven by means of a steam cylinder to which the supply of steam is controlled by the operating valve fastened to the stoker hopper.

the selection of a less desirable type of drive on account of greater simplicity.

The steam turbine drive has received considerable attention in recent years and is now built as an integral part of the stoker. It overcomes the mechanical objections to a multiplicity of small steam

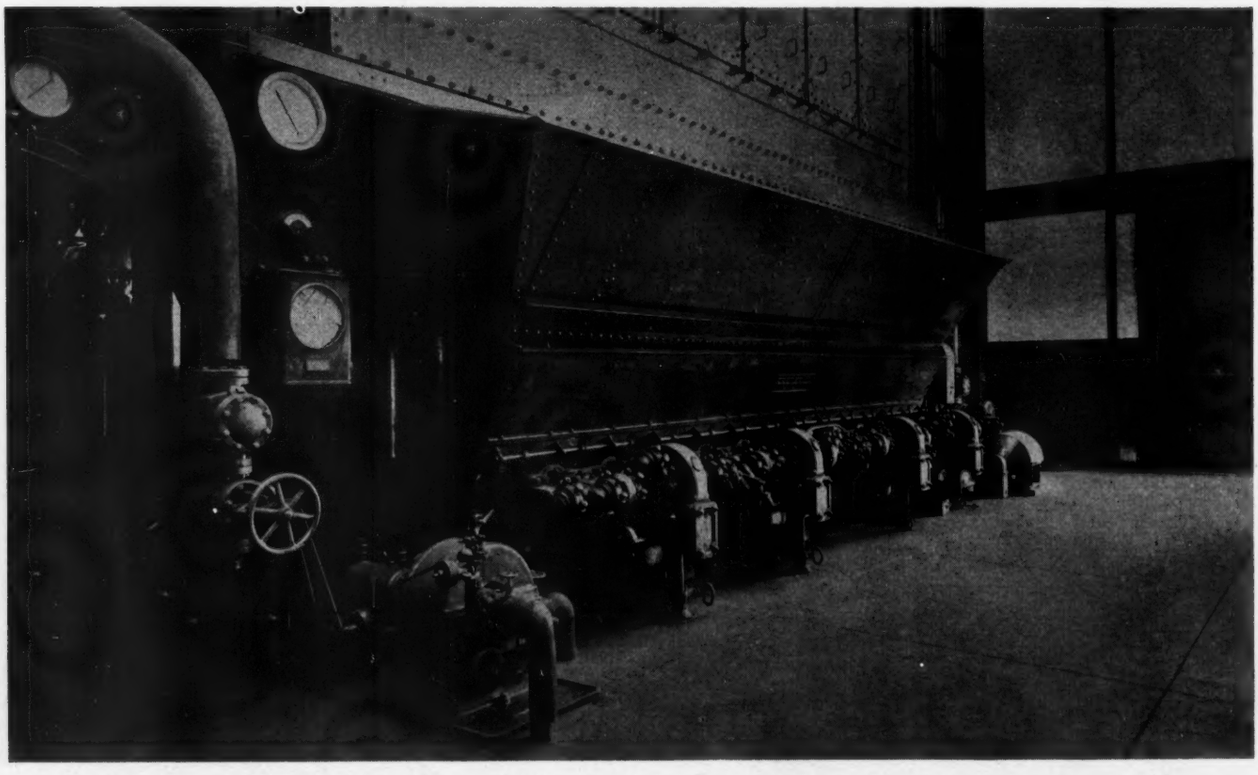
units operating on high pressure superheated steam, but the problem of properly utilizing the exhaust still remains. In many plants, this in no way complicates the heat balance, and, when this is the case, the turbine drive meets the conditions very satisfactorily. It has an extremely wide speed range, being available today with a maximum range of ten to one. Between these two limits, it has an infinite number of speeds and, therefore, makes it possible to secure a speed bearing the proper relation to the existing load. It requires no lubricated surfaces in contact with steam, and the exhaust can therefore be used for any purpose where low pressure steam is desired.

In the selection of a stoker drive it should be kept in mind that if the operator is to secure the best results, he must have at his command a stoker drive with a speed range adequate to take care of the load fluctuations and to secure small increments of speed between the two extremes. A drive which fails to meet these requirements should not be selected on account of lower first cost or greater simplicity. The difference in first cost and operating efficiency of the drive disappear immediately when compared with even a fractional improvement in efficiency due to the use of a more flexible drive.

So far as the operation is concerned, the constant speed motor with a variable speed transmission, the shunt-wound d.c. motor, and the steam turbine, all have satisfacotry characteristics. Any one of the three may be selected on the basis of local conditions and a completely satisfactory stoker control will be assured. Where there are definite objections to any one of these three forms of drive and the load variations are not greater than two to one, the variable speed a. c. motor can be employed. The four speed a.c. motor has little to recommend it and it is difficult to assume a set of conditions under which it should be used for stoker drive.

It should at all times be kept in mind that while it is desirable for best results to maintain a stoker speed as nearly as possible in proportion to the load on the stoker, there are variations in fuel conditions that require occasional departures from this relation. Where manual control is employed the operator makes these secondary adjustments from time to time as the fuel bed indicates the necessity for such change. Where automatic control is employed the function of the automatic equipment is to maintain the predetermined relation between load and stoker speed with provision by which the operator can from time to time make small manual adjustments to compensate for varying local conditions.

The cost of the stoker drive is an insignificant part of the complete plant cost, and the power consumed is an extremely small fraction of the total auxiliary power consumed. In view of the important effect that the proper drive may have on combustion efficiency, it should be selected to give the proper characteristics rather than on account of its first cost or operating efficiency.



Multiple retort, underfeed stoker driven by a.c. multi-speed motor. Power is applied to the rams from a crank shaft which passes through two-speed gear boxes. Adjustable speed d.c. motor or adjustable delivery a.c. motor may also be used with this type of stoker. Note that this installation includes an auxiliary turbine drive, shown on the left.

Bethlehem Steel Burns Blast Furnace Gas *and* Pulverized Fuel *in an* All Metal Furnace

By Eric Lundgren
Combustion Engineering Corporation, New York

THE widely fluctuating load of a steel plant power house requires a type of boiler which will follow the load curve without an appreciable pressure drop when the steam demand suddenly goes from idling to full load, and without lifting the safety valves when the demand drops from full load to practically no load within a fraction of a minute.

A certain degree of compromise is ordinarily expected in designing a steam generating unit to burn blast furnace gas and pulverized coal in the same furnace. At Sparrows Point there was no such compromise. A completely water-cooled furnace was adopted despite the prophecy of skeptics that ignition could not be maintained with a fuel as lean as washed blast furnace gas. Mr. Lundgren discloses for the first time the actual results secured from this much discussed installation.

Two years ago, when additional boiler capacity was found to be necessary at the Sparrows Point plant of the Bethlehem Steel Company, the Combustion Steam Generator was selected as the type best adapted to the conditions of the plant.

Blast furnace gas was to be the primary fuel with pulverized coal as an auxiliary to take the peaks and carry the load when sufficient gas was not available.

Two generating units were decided upon and the capacity for gas firing was specified as 90,000 lb. of steam per hour, actual evaporation. With coal fuel these units are each able to deliver from 150,000 to 175,000 lb. of steam per hour with efficiencies equalled only in the best central station practice.

The boiler plant operates at a line pressure of 275 lb. per sq. in. and an average steam temperature of about 670 deg. fahr. Each of the units has 8530 sq. ft. of steam generating surface of which 2034 sq. ft., nearly 25 per cent, is exposed to direct furnace radiation. Each boiler has three forged drums, two at the bottom and one steam drum at the top, which are machined both inside and out.

The boilers are fired at the top, the fuel being introduced "tangentially" at the four corners of the furnace and the gases are passed downward through a water screen of six rows of staggered tubes to a settling chamber where the coarser particles of ash settle out. The rear end of the settling chamber contains the superheater through which the gas passes before it enters the convection bank of the boiler The gas flow in the convection bank is upward and parallel to the tubes. From the convection bank the gas is passed through a short horizontal duct to a fin tube economizer from which it is led to a plate type air preheater and there discharged, via the induced draft fan, to the stack.

In order to get quick response from a boiler it is essential that there be as little refractory material in the furnace as is consistent with good construction and in these units the brick work was limited to four narrow piers in the corners. These were found necessary in order to avoid a complicated arrangement of bent tubes around the burners which enter the furnace through the piers. The four side walls and the roof are covered with four inch tubes, provided with metal fins so as to form a complete surface of steel. The bottom of the combustion chamber is formed by the water screen through which the gases pass on their way to the superheater. The burners are placed as high in the furnace as possible so as to allow for the maximum cooling of the gases before they enter the screen. The burners are set so that each stream of fuel will enter the furnace in a direction tangent to a fifty inch circle. Thus, a violent turbulence is created and a rotary motion is set up which persists until the gases enter the screen at the furnace bottom. The fact that the entire gaf column rotates may be readily seen by the nature so the dust deposits on the furnace tubes.

Each corner of the furnace is provided with three gas burners and two coal burners making a total of twelve gas burners and eight coal burners to each unit. When coal is being burned, all the air, with the exception of a small amount used to carry the coal from the feeders to the furnace, enters by way of the gas burners, mixing taking place when the two mediums meet on the turbulent circle in the center of the furnace. The coal burners are of the simplest possible construction, consisting of round pipes set flush with the face of the brick piers at the corners. The gas burners are of a somewhat more elaborate design as it was considered necessary to have the gas enter the furnace well mixed with the necessary air for combustion so that the large volume of gas would be completely burned out before the gas stream entered the screen. Each gas burner consists of a large cast iron box through which the secondary air is admitted. This box is fitted with four narrow ducts through which the gas is admitted, the result being that the gas enters in four thin sheets each one completely surrounded with air and both mediums moving at high velocities. Thus, ideal mixing takes place immediately the furnace is reached and the gas

is completely burned within a short distance from the burners.

The burning gases in the upper part of the furnace appear as an incandescent mass of gas completely filling the upper part and decreasing in intensity as it approaches the bottom screen. However, before the screen is reached the combustion is complete and to the operator who is familiar with the brilliant luminosity of a powdered coal furnace, the region directly above the screen looks cold. It could hardly be expected that the tangential firing of gas would show up to so much better advantage than other methods but it has been found that with turbulent firing, the heat absorption in the furnace is very much greater than can be accounted for by simple radiation from the flame to the water walls and the conventional allowance for convection to the furnace tubes. It is obvious that the rapidly revolving gas column in the furnace increases the heat transfer from the gas to the tubes by eliminating the sheet of comparatively cold gas which is always found along the walls of a furnace where the flow of the gas is

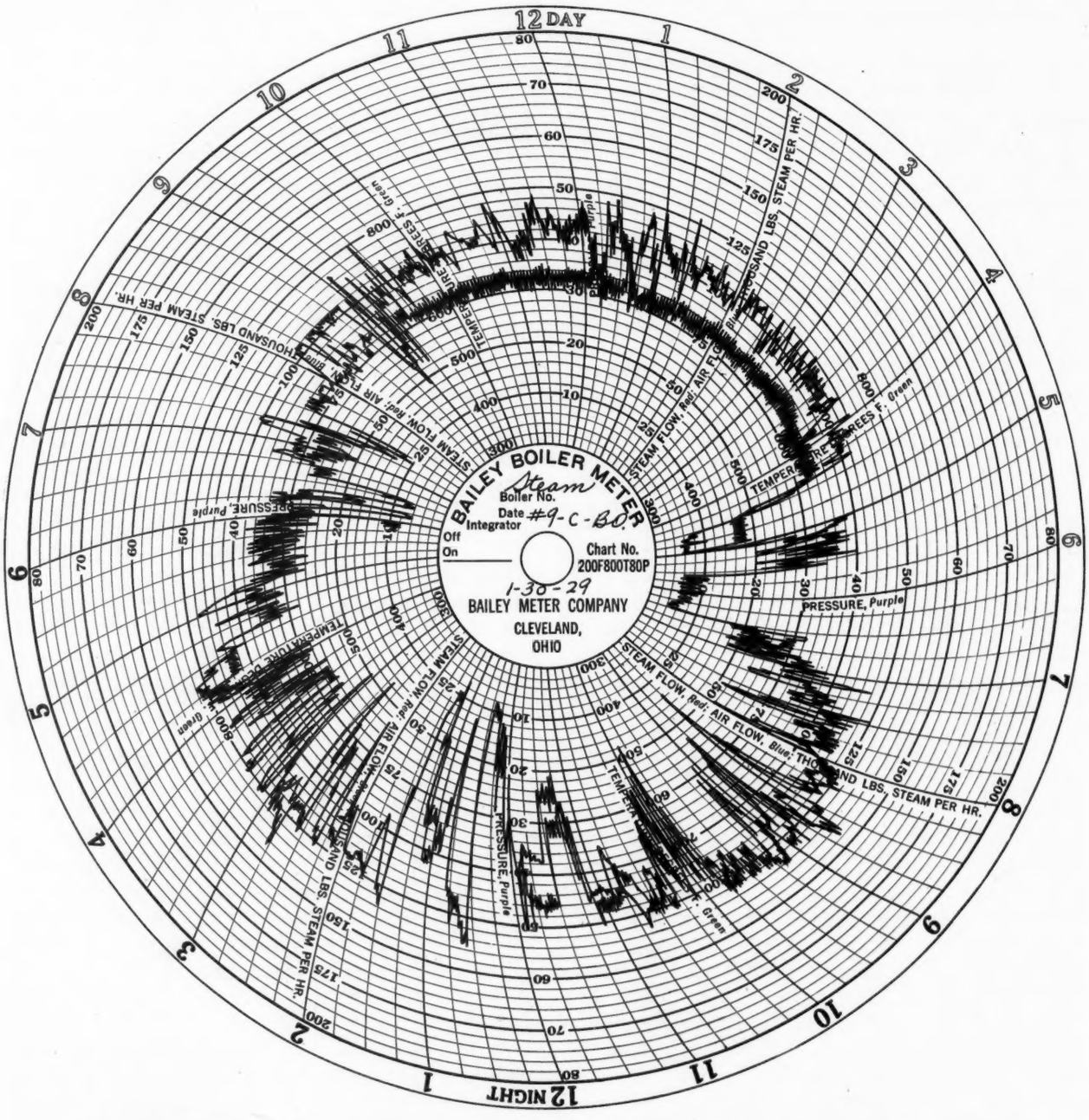


Fig. 1—Boiler Meter Chart showing load conditions during normal operation. The chart shows both the wide range of loads and the suddenness with which the peaks come on. On the day this chart was made the load was held constant from 9:30 A.M. to 4:00 P.M. for testing purposes, and coal only was fired during this period. For the balance of the period shown on the chart both coal and gas firing was used.

parallel to the walls. The low temperature of a blast furnace gas flame does not provide a high rate of radiant heat absorption by the furnace tubes and there is no doubt but that the high efficiency of turbulent firing is due to the imparting of a high velocity to the gases so that fresh gas volumes are constantly brought in contact with the tubes.

When coal is being burned, the furnace naturally assumes a different appearance and has a much more luminous flame. Where the four or eight coal streams impinge at the furnace center, the temperature is very high and the gases formed by the combustion expand and fill the space above the burners completely, at the same time setting up a violent rotation of the entire mass.

After leaving the furnace the gases pass to the settling chamber through the bottom screen where a temperature drop of several hundred degrees takes place. This screen has six staggered rows of 3-in. tubes and is equipped with three elements of soot blowers so located that all spaces can be reached. Lancing doors have also been provided should it be necessary to do hand lancing when the unit is running at high ratings with a mixture of coal and gas.

The settling chamber is a large refractory lined pit the usefulness of which is naturally most apparent when coal is being burnt. The gas velocity in this part of the unit being low, a large percentage of the ash settles out before the gas enters the more restricted passages of the boiler. This compartment also contains the superheater which consists of two rows of double loop elements distributed across the furnace width. The convection bank of boiler tubes. like the bottom screen is made of up 3 in. tubes but instead of being staggered these tubes are arranged in parallel lines in the usual manner for bent tube boilers. The convection bank is a single pass and contains no baffles, the boiler casing limiting the gas flow in the back and the fin wall in the rear of the furnace forming the front wall, the idle space being provided with a deflector for guiding the gas. After leaving the convection bank the gases pass through a short horizontal duct to the economizer which is made up of 2 in. finned tubes. A large air preheater of the plate type is placed directly under the economizer. The temperature of air at the maximum rating is about 500 deg. fahr., for either fuel.

Control of the boiler is automatic. The blast furnace gas is controlled by means of butterfly dampers and the coal supply is regulated by varying the feeder speed. Eight screw feeders supply coal from overhead bins which in turn are filled from a separate coal preparation plant located some distance from the boiler house. Five pulverizing mills supply the coal to air transport pumps which deliver it through an overhead pipe line to the powdered coal bunkers in the boiler house. Before entering the mills the coal passes through steam heated rotary dryers.

Two forced draft fans supply the necessary combustion air for each boiler but only one induced draft fan is provided. Each boiler has also one primary air fan for supplying the small amount of air necessary for bringing the coal from the feeders to the furnace. This fan takes a part of its air from the hot air duct the rest being made up with air from the room so as to bring it down to an average tempera-

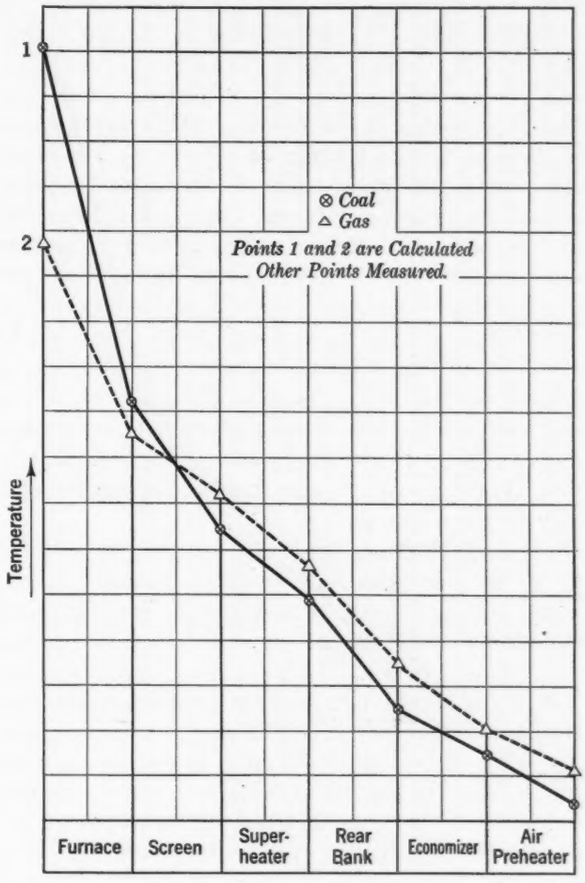


Fig. 2—Comparison of flue gas temperatures leaving the various parts of the unit with coal firing and with gas firing. The ratings were identical at all times.

ture of about 250 to 300 deg. fahr. The boilers are controlled from a central board which is equipped with the necessary instruments. In addition to the usual flow meters, temperature indicators and recorders, there is a CO_2 meter for each unit, blast furnace pressure gages and an indicator giving the amount of pulverized coal in the bunkers. These bin indicator readings also appear in the coal preparation house so that the mill operator is guided by the boiler plant requirements. The switching of pulverized coal from one bunker to another is done electropneumatically.

Two feed water connections are provided in the top drum of each boiler and a feed water regulator is inserted between the economizer and boiler on each inlet. The feed water for these steam generators is mostly condensate, the balance being made up by raw water treated in a Zeolite system and passed

through a set of deaerators designed and built by the Bethlehem Steel Company. The temperature of the water entering the economizer is about 190 deg. fahr.

The boiler plant in which these generators are installed, has a number of other steam boilers of standard design Some of them are rather old while others are of a recent date. It has been found practical to keep the boilers running at a practically constant rating and to meet the load fluctuations with the steam generators in so far as possible. As can be seen from the flow meter chart (Figure 1), the peaks come on suddenly and it is not unusual to find an instantaneous rise in the flow line representing steam fluctuations having a range of 125,000 lb. per hour. Such a peak may be of only a few minutes duration, but again may last for hours. The chart (Figure 1) shows a number of sudden increases of over 100,000 lb. per hour. When a sudden steam demand appears the gas valves open automatically and whatever gas is available is used in keeping the pressure in the boiler. Should the demand be greater than the supply of blast furnace gas available, the pulverized fuel feeders are started and the additional heat is supplied by coal. Most of the peaks are of a comparatively short duration, and usually they disappear as suddenly as they appear.

With such fluctuations it is naturally rather difficult to regulate the feed water, especially as the boiler, when figured according to conventional methods, is operating at over 700 per cent of rating at the extreme peaks. There is a rise of several inches in the water level when the rate of steam production is suddenly doubled or tripled and a corresponding drop when the load is lowered, but it has always been possible to keep the water within reasonable limits and in sight in the glass. This is due to the fact that the feed water pipes are large for the size of the unit and two of them work in parallel. When these units were being designed, it was thought that there might be some danger of priming on sudden increases in rating and for this reason the units were equipped with steam separators. A great number of tests have been made to determine the quality of the steam to the superheater and in all cases the moisture content has been found to be well below ½ per cent under even the most unsteady load conditions. The water removed from the steam by the separators is discharged through traps to the sewer as the quantity is too small to make it worth while to recover its heat content.

These boilers are kept on the line continuously for several months at a time with little or no difference in load conditions during the twenty-four hours of the day. The feed water treatment seems sufficiently effective to prevent scale formation. As previously mentioned, gas is the main fuel and whatever peaks occur beyond the capacity of the fans and gas burners are met with coal firing. When the peak loads are of short duration, or with coal alone as fuel, the furnace requires practically no attention, but if the unit is operating under high continuous loads with fuel mixtures containing large quantities of blast furnace gas, it is necessary to use the soot blowers in the screen and on a few occasions hand lancing was necessary to clean the spaces between the screen tubes. If coal alone is burned very little slag builds up as the coal is a good grade of Eastern bituminous with a comparatively high fusing point of the ash.

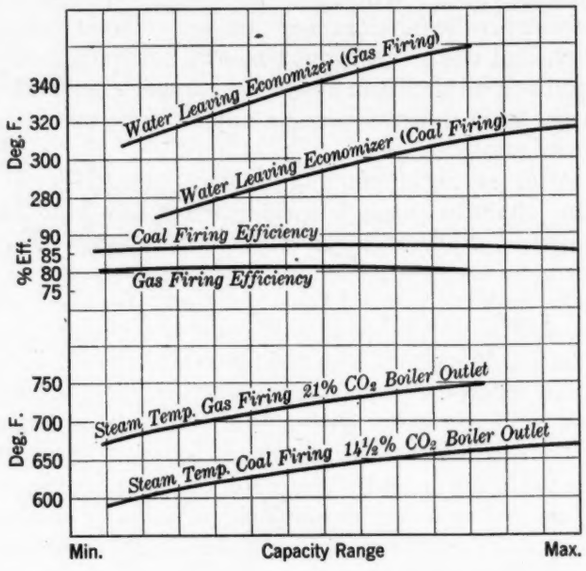


Fig. 3—Chart showing relative efficiencies with coal and gas firing throughout operating range; also comparative temperatures of water and steam

The gas as fired contains a certain amount of dust carried over from the blast furnaces and this combines with the ash from the coal, and fluxes, forming lumps which fall from the walls and have to be removed by hand lancing. Approximately fifty per cent of the balance settles out under the screen from where it is removed through the gates in the bottom and hauled out in carts. The ash leaving the stack is white and the appearance of the combustion products is not very much different for gas and for coal.

The temperature of the preheated air used for combustion, varies from 400 to 500 deg. fahr., at the highest ratings specified for the two fuels. The air preheater is of the plate type and employs the counterflow principle. The elements are closely spaced and provide one-half inch lanes for both flue gas and air. This spacing has proven to be entirely satisfactory and no fouling of the plates has been found under any method of operation. When the heated air leaves the preheater it passes into a belt duct, which with the heater itself, completely circles the setting. From this duct the air for the burners is taken off at each of the four corners. A tap for the primary air fan is also provided for supplying hot air for the pulverized coal feeders.

With the exception of one turbine driven pump for the control system, the auxiliaries are all motor

driven, 25 cycle alternating current being used for all fans and direct current for the coal feeders and ash gates. For convenience in operation, all fans were placed on the firing floor making it unnecesssary for the fireman to leave this level for any reason. Observation doors, placed at a convenient height above the operating floor, give a very good view of the active combustion zone, supplementing the instruments in guiding the operation of the furnace. The bottom of the economizer is also on this floor level so that any work which needs to be done to this apparatus can be done from the firing floor. Gage glasses are easily visible from the front of the boiler at a convenient elevation above the eye and the feed water regulators are located within easy reach of the floor. From an operating point of view, nothing more could be desired as far as convenience is concerned and the units can be handled with the minimum amount of exertion on the part of the fireman. The total labor of operation is unusually small, being limited to the occasional removal of ashes. Electric interlocks are provided so that if the induced draft

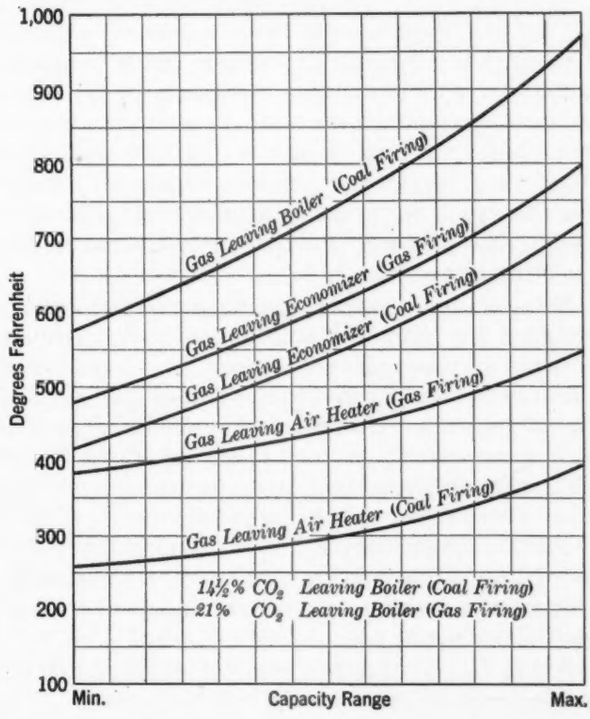


Fig. 4—Chart showing comparative temperatures, with coal and gas firing, of flue gases leaving the boiler, economizer and air preheater. These temperatures are indicated throughout the operating range

fan kicks off, feeders and forced draft fans follow to prevent flooding the boiler house with hot gas.

As far as the author knows these steam generators are the first large units burning blast furnace gas in a completly water cooled furnace and contrary to general belief it has been found possible to burn the gas so completely that the most careful Orsat samples fail to show any trace of carbon monoxide. This installation has also shown that a rapidly revolving gas column in the furnace will materially increase the heat transfer to the furnace tubes causing a rapid temperature drop. This makes it possible to operate with large quantities of gas while burning coal, without slagging the tubes in the first pass, which in a unit of this type consists of the bottom screen. It is true that conditions for preventing slag are very favorable as the gas stream is not concentrated on a comparatively small area of the tube bank, but the entire pass is open as in a straight tube, single pass boiler. Whatever slag formation occurs is not on the tubes in the screen but in the burner zone. Before this formation builds up to any appreciable size it falls off and is easily disposed of. When burning gas a loose, soft dust accumulation settles on the tubes which falls off when it reaches a thickness of about ⅛ in. This disintegrates completely when it hits the screen tubes and is carried off with the draft.

The heat liberation when operating with gas at the highest rating is over 35,000 B.t.u. per cubic foot, and this rate can be maintained without any gas leaving the furnace unburned. This liberation corresponds to a conventional boiler rating of about 500 per cent which is unusual for blast furnace gas or similar fuel. Heat liberation rates, combined with overall efficiencies as found in this unit, do not seem possible without the aid of the high turbulence produced by tangential firing. With the amount of gas forced into these furnaces by any other method, it is probable that stratification would take place and that a large percentage of the gas would pass through the screen and into a zone, too cool to maintain ignition. That this initial installation is a success is evidenced by the fact that the Bethlehem Steel Company recently contracted for four more steam generators of this type to be installed in two other plants.

Due to the intense and persisting tubulence in a tangentially fired unit it is practically impossible to make it smoke under any conditions. When burning a good grade of Eastern bituminous coal, the carbon dioxide content in the gases in the furnace can be brought up to over 17 per cent with a perfectly clear stack. The limiting factor in lowering the excess air is neither smoke nor the production of carbon monoxide, but the fusing point of the ash. It is practical, with coal alone, to operate with over 16 per cent CO_2 in the gases leaving the furnace and this naturally aids in maintaining a high operating efficiency. With gas firing the flue gas leaving the furnace averages about 22 per cent CO_2 which corresponds to about 14 per cent excess air with the gas used. The gas is washed before being used in the furnaces and reaches the burners at about 70 deg. fahr. and is saturated with moisture at that temperature. Occasionally some condensation of moisture takes place in the burner casings and a sticky mud is formed which has to be removed through hand holes provided for the purpose. Measured at a temperature

of 60 deg. fahr. the gas contains about 108 B.t.u. per cubic foot or 1320 B.t.u. per lb. The coal averages about 25 to 30 per cent volatile and 13,650 B.t.u. per lb. as fired, with a moisture content of about one per cent and ash of about 9.5 per cent.

It is interesting to note the wide difference in performance of the same unit with the two different fuels. Figure 2 shows the relative range of temperatures throughout the unit when gas and when coal is used at the same rating. The calculated initial temperatures show a difference of about 900 deg. fahr. at this particular rating. After passing through

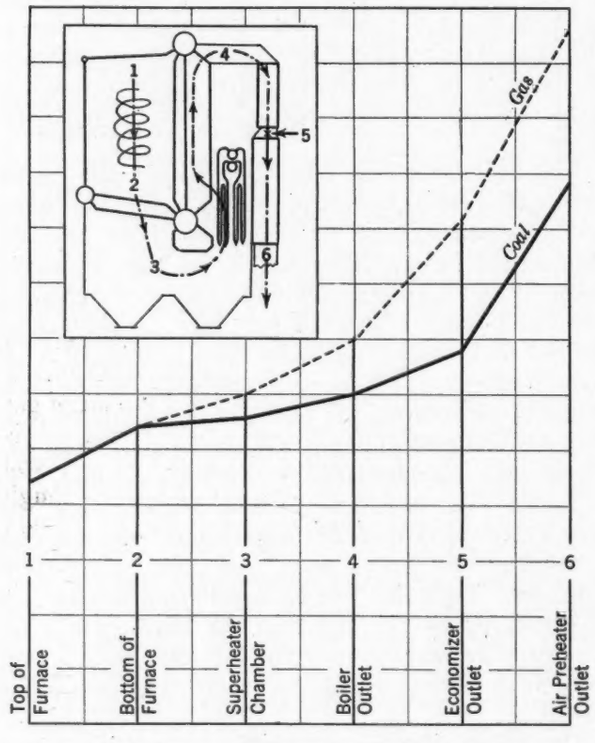


Fig. 5—Draft diagram of unit and curves showing comparative draft losses with gas and coal at various points in the unit. These recordings were made at identical ratings

the completely water cooled furnace the difference in temperature dropped to well below 200 deg. fahr., the line for coal still being above the line for gas. About half way through the screen the two lines cross and from then until the flue gas leaves the air preheater, the difference becomes greater. The relation of the gas weights in these two tests was approximately as 1:1.54 for coal and gas respectively.

The heat balances for these two tests show the reason for the lower efficiency with gas firing as compared to coal firing in the same unit and under the same load.

It will be noted that the dry gas loss for gas firing is roughly two and one-half times as great as that for coal while the hydrogen loss for gas is less than two-thirds that of coal. Due to the fact that the blast furnace gas is saturated when it reaches the burners, the loss due to moisture in the fuel is twice as great for gas as for coal, but still of relative unimportance. Carbon loss is, of course, completely eliminated in gas firing and radiation amounts to the same in both cases, or, in a water cooled unit, they are so nearly identical that they can not be distinguished.

The following table gives the heat balance for the two fuels.

Losses, per cent	*Coal*	*Gas*
Dry Gas	5.9	14.9
Hydrogen	3.5	2.1
Moisture in Fuel	.1	.2
Moisture in Air	.1	.1
Unburned Carbon	1.5	0.0
Radiation	2.0	2.0
Total Losses	13.1	19.3
Heat Absorbed (By Diff.) per cent	86.9	80.7

Figure 3 shows the efficiency curves of the unit at various ratings when fired with gas and with coal. The average difference of the two being roughly 6 per cent in favor of the coal. As a large percentage of the heating surface of the unit is in the form of economizer and air preheater surface, the curves are practically horizontal, the greatest variation throughout the operating range being less than 2 per cent. The highest efficiency for coal is 87 per cent and for gas firing 81 per cent.

Maintaining a constant steam temperature in a unit intended for combination firing, is practically impossible with an ordinary superheater. In designing a unit of this kind a compromise must be effected between the steam temperatures obtained with each of the two fuels. At maximum rating with coal firing the superheated steam temperature is 670 deg. fahr. while at the maximum rating with gas firing the steam temperature is about 740 deg. fahr. The lower pair of curves (Figure 3) show a temperature difference of about 70 degrees throughout the operating range of the unit.

Figure 3 also presents two curves showing the temperature of water leaving the economizer. The average difference through the range is about 45 degrees and there is no tendency for the temperature lines to converge at either end.

Figure 4 shows the temperature of the gases leaving various parts of the unit. The curves include the entire capacity range of the unit and show results with both gas and coal firing.

Figure 5 shows the relative drafts necessary for coal and gas, the difference being due to the larger gas volume and higher temperature of the flue gas from the blast furnace gas. Curves are plotted at identical ratings and corresponding amounts of excess air.

Phosphate Treatment *of* Boiler Water

By EDWARD P. PRICE

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With the increase of boiler sizes and pressures, the problem of feed water treatment has assumed growing importance. In this article, the author briefly reviews the principal difficulties incident to the rapid changes in operating practice and reaches certain conclusions which are the result of experiments conducted on a strictly commercial basis and extending over a period of two and one-half years. The thoroughness with which these experiments were conducted and the comprehensive manner in which the findings are presented should make this article of very definite value to all who are interested in the subject.

IT may be said that in the past one of the greatest, if not the greatest, problem confronting the operators of steam boilers was the problem presented by the boiler water. It is probably true that today a vast majority of boiler operators suffer greatly from the same source of trouble that proved so discouraging to the earliest experimenters. Many mistaken ideas in regard to boiler water treatment have prevailed and some practices appear to be founded upon superstition rather than upon reason and experimental results. This is probably due to the fact that boiler water troubles are chemical in nature, and the average boiler operator knows little of chemistry. Due to the increase in the cost of fuel and to the increase in size and use of steam boilers, much effort has been expended in the past few years to determine proper methods for boiler water treatment. This has proven to be not only a fertile field for the chemist, but has taxed his ingenuity and resourcefulness to the limit. Not only did each water present a different problem, but each plant had its own peculiarities, and each plant operator, due to his ignorance and distrust, presented additional problems of a personal nature, that in many instances were insurmountable. The cry of the old-timer was "Do not make a chemical vessel out of a boiler," and it has been difficult to convince him that a boiler is a chemical vessel and should be controlled by intelligent chemical treatment.

The work of the chemist was at first feeble and uncertain, and often resulted, due probably to his ignorance of plant operations, in a waste rather than a saving This caused adverse criticism, but his mistakes were soon overshadowed by his success and confidence in his ability increased. This success was further increased by improvements in plant processes, which permitted the condensation of exhaust steam and the consequent reduction in the make-up water. This make-up water was treated to prevent scale formation in the boiler, and practically all substances that form insoluble precipitates with calcium and magnesium, were used in water treatment. This resulted in scale-free operation, but trouble was experienced from foaming; and blowing down a portion of the boiler water was resorted to, to reduce the concentration and prevent foaming. This blowing down produced a waste of heat and a corresponding increase in make-up water, so that efforts were made to reduce or eliminate this practice. It was found that the concentration necessary to cause foaming depended upon the substances present as foreign matter in the water, and the rate of steam generation. The most objectionable substances were found to be such soap forming substances as animal and vegetable fats and oils, resins, gums and coal tar. Later refinements in design further reduced the percentage of make-up water, and made it possible to evaporate all make-up water, so that neglecting leakage, the boiler water could be kept free from dissolved solids. This eliminated scale troubles and blow-downs, but it was found necessary to treat the water in the boiler to prevent corrosion and caustic embrittlement, which in some cases were more serious than troubles arising from scale formation. These problems were new and the chemist had little information to refer to but he soon found out that corrosion could be reduced by keeping the boiler water alkaline and as free as possible from dissolved oxygen. In regard to embrittlement he had little to say, but it was observed that waters high in sulphates caused little or no trouble from this source, and the American Society of Mechanical Engineers drew up a code based upon these observations, which specified that a certain ratio of sulphate to total alkalinity be maintained in boiler waters to prevent caustic embrittlement.

In order to keep the total dissolved solids of the boiler water as low as possible, and yet maintain the prescribed sulphate alkalinity ratio, it is necessary to maintain as little alkalinity as possible and still prevent corrosion. To do this the proper chemical for preventing scale formation should be chosen. Since about sixty-five per cent of the soda ash in a boiler water decomposes at a steam pressure of 200 lb. per sq. in., this is the highest pressure at which an attempt should be made to use soda ash on account of the resulting high alkalinity. As such organic substances as oxilates decompose at higher pressures, present problems in testing, and are costly, they are undesirable. Silicates are impossible since calcium and magnesium silicate scales are difficult to deal with, and chromates are undesirable because of the negative solubility temperature co-efficient of calcium chromate. The aluminates may not be desira-

ble on account of the solubility of calcium alumnate, and because of the formation of alumino-silicate deposits, at points of slow circulation of boiler water, that are difficult to remove by washing. Although fluorides are stable at higher pressures their close chemical relation to the chlorides excludes them on account of their tendencies to cause corrosion.

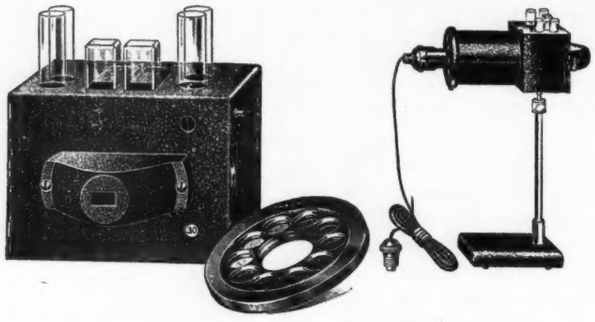


Fig. 1—Hellige Comparator which gives the pH value of boiler water; used for checking alkalinity

From the standpoint of stability the phosphates meet all requirements, and the precipitates formed with calcium and magnesium are very insoluble. Since phosphates do not decompose and increase the alkalinity of the boiler water, this alkalinity can be maintained at a very low value, and there is therefore, little reason to fear caustic embrittlement. In fact, unless some caustic is used, when boiler water is treated with di-basic sodium phosphate it has been found to gradually become acidic. This, therefore, puts the question of alkalinity entirely under command so that it can be maintained at any point. The optimum pH value can thus be maintained to prevent corrosion, and at the same time permit protection from caustic embrittlement without the use of a large quantity of sulphate. This method of treatment produces clean surfaces, clear water and good steaming conditions, due to the extremely low concentration of dissolved solids. Where the make-up is evaporated and the raw water leakage is not excessive the total dissolved solids should not exceed 1,000 p.p.m.

The point to be emphasized in conditioning boiler water is to maintain at all times the proper concentrations. It is of little value to occasionally see that the conditions are proper, and permit long periods of operation with improper conditions. It, therefore, becomes necessary to systematically test the water in each boiler, and correct all irregularities by the proper addition of chemicals. The frequency of such tests will have to be determined by local conditions, but at least it should be frequent enough to prevent the development of improper conditions of the boiler water. Chemical analyses of water to determine phosphates, sulphates and hydroxides are too difficult for the ordinary layman to perform without careful training, but methods of testing, sufficiently accurate for boiler water conditioning, have been devised which any boiler operator can be taught to make in a short time.

To bring the discussion to a special case the method used in treating the water in two 2,000 hp. 400 lb. per sq. in., Babcock and Wilcox boilers for the past two and one-half years will be considered. The make-up water for these boilers is evaporated and the quantity needed averages about one per cent. The raw water, which is evaporated without treatment, has the following analysis.

RIVER WATER ANALYSIS

Irons	*p.p.m.*
Na	21.03
Mg	15.45
Ca	62.80
SO_4	30.00
CL	13.81
HCO_3	240.50
CO_3	12.36
OH	0.17
Total Alkalinity	4.32
PH Value	7.9
Total Solids (Calc)	273.90
Total Solids (105 deg. cent.)	277.80
Total Solids (108 deg. cent.)	275.80
Total Solids Residue	243.00

When these boilers were installed it was recognized that proper boiler water conditioning was quite necessary to insure good operation, and the phosphate treatment was adopted. The necessary chemicals and equipment were purchased, and when the boilers were put in service di-basic sodium phosphate was used to maintain a concentration of about 30 p.p.m. of free soluble phosphate, and the sulphate

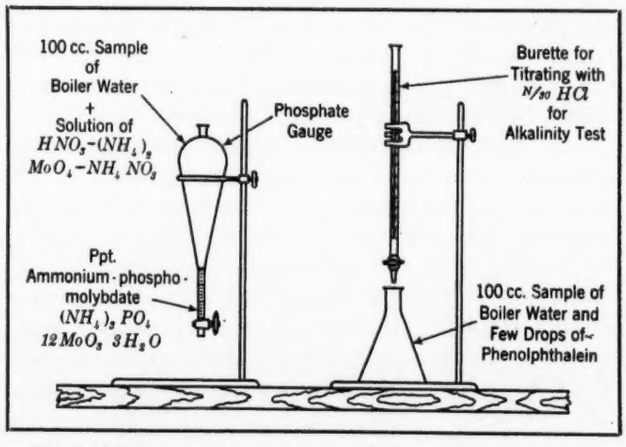

100 cc. Sample of Boiler Water + Solution of HNO_3-$(NH_4)_2$ MoO_4-NH_4NO_3
Phosphate Gauge
Burette for Titrating with N/50 HCl for Alkalinity Test
Ppt. Ammonium-phospho-molybdate $(NH_4)_2PO_4$ $12MoO_3$ $3H_2O$
100 cc. Sample of Boiler Water and Few Drops of Phenolphthalein

Fig. 2—Phosphate gage, burette and flask used for determining alkalinity

carbonate ratio was not less than three to one. This treatment kept the total solids down to about 1,000 p.p.m. and the alkalinity of the water was extremely low. In fact, after about four or five months of this treatment the alkalinity was too low to cause a color

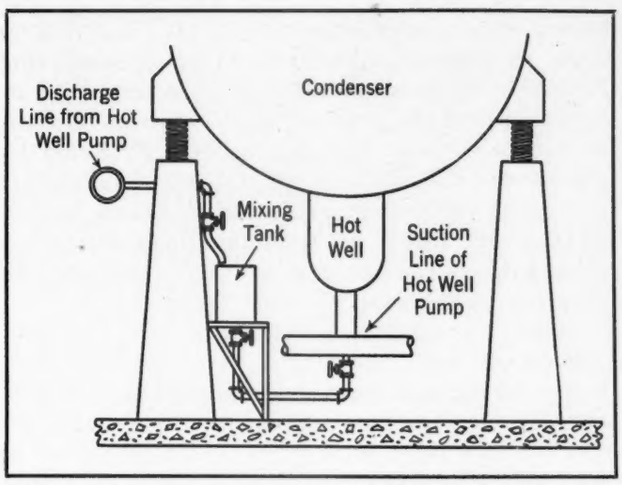


Fig. 3—Arrangement for feeding chemical solutions into the boiler through the condenser. The usefulness of this arrangement is limited to periods when only one boiler is in service.

change with brom-phenol-blue, and sodium hydroxide was used to bring the alkalinity up to about 50 p.p.m., which caused a pH value of about ten. This method of treatment was continued for about one and one-half years and no blow-downs were ever necessary, due to high concentrations in the boiler water, and no other objectionable conditions were observed. Tests were made once a day, and the necessary chemicals were added through the condenser hot well when only one boiler was in operation during light load periods.

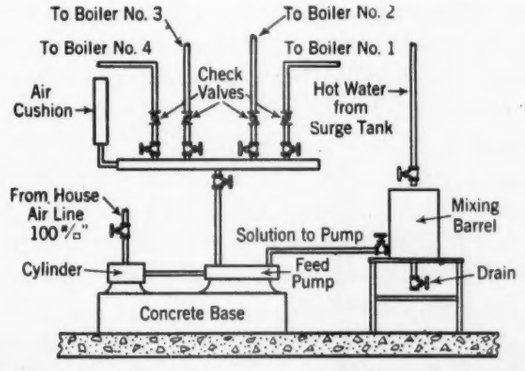
A surface condenser was used and the water was not allowed to come in contact with the air at any point in the cycle. No deaerators were used, but Winkler tests of water samples taken from the hot well, the surge tank and the boiler feed mains have shown an average oxygen content of much under 0.03 cc. per liter. Also a careful check on condenser leakage is had by the use of a portable conductivity meter. It has also been found that the rate of change of the phosphate content of the boiler water is a sure indicator of leakage. With this method of treatment the same water has been kept in a boiler for a period of about six months without blowing down, and upon inspection all surfaces appeared to be in perfect condition.

When the turbine was taken apart, after almost constant operation for two and one-half years, it was found that the high pressure blading was covered with a scaly deposit. This deposit was caused by chemicals that were carried out of the boiler by the moisture in the steam and was easily washed off with water from a hose. It is thought that such deposits can be washed off by running wet steam through the turbine when it is turning at low speed. No deposits of this nature have been observed at other places, and the deposits on the turbine blades are slow in forming.

Prof. Straub of the University of Illinois has conducted laboratory tests which show that phosphate is about 500 times as effective as sulphate in prevent ing embrittlement. Although phosphate had never been tried in this way on a commercial basis, it was agreed in April, 1928, to discontinue the use of sulphate and make use of phosphate for inhibiting embrittlement and preventing scale formation. The boilers were emptied of all water containing sulphate and filled with water containing only sodium phosphate and sodium hydroxide. Since that time the boiler water has contained between thirty and fifty parts per million of free soluble phosphate, and has a pH value of about ten. The advantage of this method is that the concentration of the total solids can be kept at a very low figure. Below is a typical analysis of the boiler water:

Hydroxide (OH)	35.2 p.p.m.
Carbonate (CO_3)	53.6 "
Bicarbonate (HCO_3)	0.0 "
Sulphate (SO_4)	21.5 "
Chloride (Cl)	13.2 "
Phosphate (PO_4)	41.8 "
Silica (SiO_2)	6.7 "
Iron (Fe)	1.3 "
Calcium (Ca)	1.4 "
Magnesium (Mg)	0.6 "
Sodium (Na) Calc	138.7 "
Suspended Material	4.9 "
Total Dissolved Solids	358.0 "

With such a low concentration of solids it is expected that turbine blade scale will be slow in forming on account of better steaming conditions, and



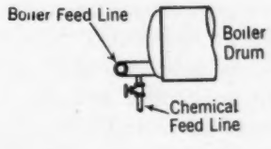


Fig. 4—Arrangement for feeding chemical solutions to any boiler at any time. This arrangement is more satisfactory but more expensive than that shown in Fig. 3.

less scale forming substances in the water that is carried away by the steam.

The boilers have operated for about eighteen months without the presence of SO_4 in the water in

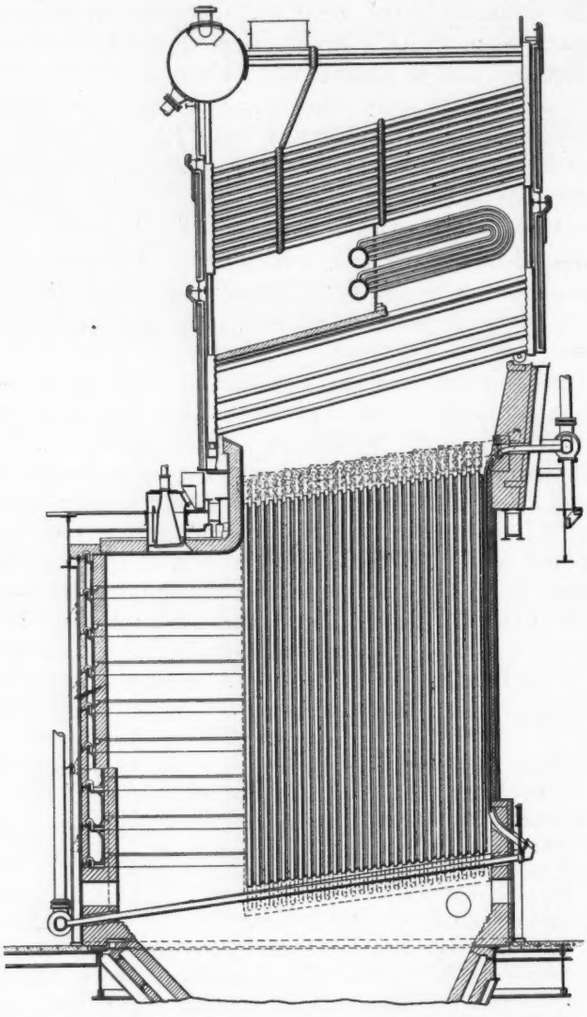


Fig. 5—Sectional elevation of one of two 2,000 hp. boiler units on which the experiments were conducted. These boilers operate at 400 lb. pressure and are fired by pulverized fuel.

appreciable amounts. They have been carefully inspected several times, and no ill effects have been found. The only trouble experienced with the boilers that may be caused by the water is that copper gaskets that were used in the tongue and groove joints in pipe that carried boiler water were found to disappear as though they were being acted upon by chemicals or subjected to electrolysis. This action has been very slow and the joints that have leaked have been provided with soft iron gaskets which as yet have given no trouble. No explanation has been found for the disappearance of this copper since the water contains no chemicals that will react with copper, and since electrolytic action would cause the iron to disappear instead of the copper.

Due to the facts that no blow-downs have ever been necessary, that no scale deposits have ever been formed, that no corrosion is taking place and that no signs of caustic embrittlement are present, this method of boiler water conditioning is considered to be well worth the time and small expense necessary to maintain these ideal conditions. It should be remembered that not only has this treatment made it possible to keep boilers in operation for long periods of time, but also it has not caused any damage to other pieces of equipment or hindered in any way the operation of the plant.

From this experiment, conducted on a strictly commerical basis, there appears to be no logical reason for the maintenance of the sulphate carbonate ratio, where phosphate treatment is in use, and therefore the increase in total solids caused by the use of relatively large quantities of sulphate is not only undesirable, but unnecessary. This has been the opinion of the chemist for some time, but due to the fact that this method had not been tried on a commercial basis, the operating companies were not inclined to look on it with favor, regardless of the obvious advantages. It is thought, however, that such an experiment as the above, covering a period of eighteen months continuous operation is sufficient to encourage other operators to use phosphate instead of sulphate for inhibiting caustic embrittlement. This, together with low alkalinity, will greatly reduce the concentration of salts in boiler water, preventing a large per cent of the carry-over with its detrimental results.

Mechanical Stokers on Ships

TWENTY-SIX vessels of the large fleet of steamships operated by the "K.P.M." Company of Amsterdam are equipped with mechanical stokers of the single retort underfeed type. Altogether a total of forty-seven water tube boilers on these vessels are stoker-fired, and the Company reports large savings in coal consumption, and marked improvements in operating and labor conditions.

This Company is chiefly engaged in inter-insular traffic in the Dutch East Indian Archipelago and operates 136 ships with a gross tonnage of 266,000. They have found the use of stokers particularly advantageous from the standpoint of utilizing the output of their own coal mines in East Borneo. Although the coal from these mines shows good analysis figures, it has been extremely difficult to burn it on hand-fired grates, whereas the stokers are using it very successfully.

A paper on this development was presented at the last World Power Conference in London.

Fig. 1—Lime and Soda Ash Filtration and Base Exchange Softening Plant, Boby type, installed at Welbeck Colliery

Water Softening Practice *in* Great Britain

Improved Types of Reagent Feed Gear and Combined Lime and Soda Ash and Base Exchange Treatment the Chief Features for Boiler Feedwater

By David Brownlie,
London

ALTHOUGH more and more attention is now being concentrated upon the subject of boiler feed treatment, not only for power stations but also industrial installations, it is still however a badly neglected field. Some years ago I showed that the average total hardness of the feedwater going into the boilers of Great Britain was 12 deg. (twelve grains per gal.), which corresponds to about 2000 tons of scale a week deposited in British boilers. Almost certainly the United States, Germany and France are doing no better in this respect, and it is startling to reflect that probably the world carries on somehow with much over 500,000 tons of scale every year formed in steam boilers.

It will be remembered that two general methods are available for softening water, the first of which is the use of lime and soda ash. The latter is added to precipitate the permanent hardness (calcium sulphate) as calcium carbonate, while lime deals with the temporary hardness (calcium and magnesium bicarbonate) and also precipitates calcium carbonate. Obviously the principle depends on the greatly different solubilities of various salts, the main figures in this connection being as shown herewith.

SOLUBILITY OF VARIOUS SALTS IN PURE WATER AT 60 DEG. FAHR. (16 DEG. CENT.)

(Parts of Anhydrous Salt per 1000 Parts of Water)

Calcium Sulphate	1.970
Calcium Carbonate	0.013
Calcium Hydroxide	1.690
Calcium Chloride	692.000
Calcium Nitrate	548.000
Magnesium Sulphate	333.000
Magnesium Carbonate	0.970
Magnesium Hydroxide	0.280
Magnesium Chloride	541.000
Magnesium Nitrate	727.000
Silica (SiO_2)	0.003
Sodium Carbonate	168.000
Alumino ferric (as aluminum sulphate)	350.000
Sodium Sulphate	138.000
Sodium Chloride	359.000

Consequently lime and soda ash never give a zero hardness water, but say three to five deg. under the best conditions, if only because $CaCO_3$ is itself slightly soluble, especially in the presence of other soluble salts that do not cause hardness.

The other method is the use of Base Exchange materials, that is, special and

Mr. Brownlie presents in some detail the principal methods of feedwater treatment in use in Great Britain, analyzes the trends that are evident in this field, and describes typical installations of the four systems that are used most extensively. Those who are interested in this important subject will benefit by reading this comprehensive treatment of foreign practice.

very complicated silicates of sodium and aluminum which will react immediately with the calcium and magnesium salts in hard water, and merely by running through will give a zero hardness water. Essentially the principle is that the sodium of the

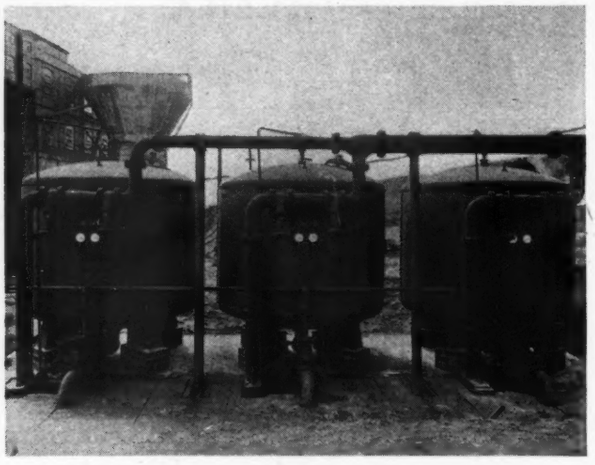


Fig. 2—Closed Pressure Sand Filters installed in conjunction with Lime and Soda Ash Base Exchange Plant at Welbeck Colliery

sodium aluminum silicate is replaced by calcium and magnesium, and this reaction goes on until the bed of base exchange material is exhausted; that is, all the sodium has been replaced. The temporary hardness, calcium and magnesium bicarbonates, reacts so that the calcium and magnesium are retained by the base exchange material, and the equivalent amount of sodium goes into solution as sodium bicarbonates. In the same way, for the permanent hardness, the calcium sulphate reacts and the water is completely softened with the formation of the equivalent amount of sodium sulphate. Then, to revive or regenerate the bed, there is poured through it for a short period a strong solution of salt which reforms the sodium aluminum silicate, and the displaced calcium and magnesium run to waste in the spent brine as calcium and magnesium chloride, the plant being ready for use again. This gives an absolutely zero hardness water, but contains in solution, as alkaline sodium bicarbonate, the equivalent of the temporary hardness as well as, of course, sodium sulphate.

The question of the relative advantages and disadvantages of the lime and soda ash treatment as compared with the base exchange method would require almost a volume for complete consideration, but essentially it is now being realized that for medium and large size steam generation plants, the ideal is often to combine the two systems in series on the "dual" principle; that is, first treating with lime and soda ash to reduce to a total of say 5 deg. hardness, and then following this up with base exchange treatment so as to give absolutely zero hardness, with only a very small amount of soluble bicarbonate; this approximately represents the combined advantages of both systems.

In this connection, it will be interesting to give the present situation with regard to water softening practice in Great Britain, which can be summed up as the use of improved types of automatic reagent feed gear for lime and soda ash plants, and the combination of the latter with base exchange treatment, especially for boiler feed purposes. It is significant also that increasing attention is being given to the softening of water for locomotives and also on board ship. Incidentally, the latter is practically a new field, equally as regards the make-up water for the boilers and for general use, as for example in the laundry plant so as to save soap.

There are more than twenty firms in Great Britain manufacturing water softening plants, but in the present contribution I propose to deal with only four of the chief of these; that is, in alphabetical order, Messrs. William Boby & Co., Ltd., of London, the Kennicott Water Softener Co., Ltd., of Wolverhampton, the Paterson Engineering Co., Ltd., of London, and United Water Softeners, Ltd., London. Each of these firms has, of course, supplied hundreds

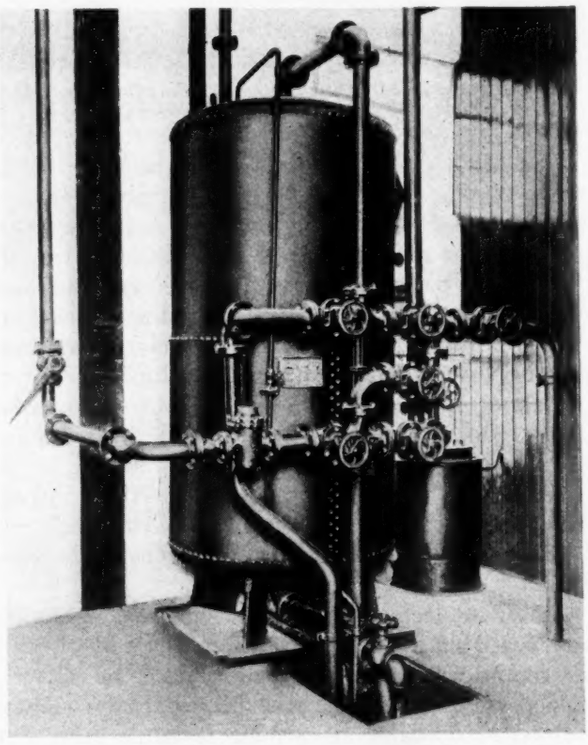


Fig. 3—"Boby-Azed" Base Exchange Softening Plant at Bowater Paper Mills, Ltd.

of water softening plants on lime and soda ash or base exchange principles, or the two combined, and they also have their own special form of base exchange plant, while it may be noted that in Great Britain the advantages of combined water softening, exhaust steam heating and oil elimination are now beginning to be more or less widely understood; that

is, using all the exhaust steam that may be available for heating the raw water, carrying out the purification in the hot condition, and then finishing with oil elimination based on the use of coagulents, followed

Fig. 4—Installation of Kennicott Water Softening Plant at Barrow Paper Mills Company, Ltd.

by filtration to remove every trace of oil, as represented by a water which is entirely clear when placed in a colorless glass in front of a black and white striped surface, a most severe test.

Messrs. William Boby & Co., Ltd., supply Boby lime and soda ash and Base Exchange plants using their material Azed, as well as much auxiliary equipment in connection with water softening, filtration, and treatment generally.

For the lime and soda ash plant the reagent gear consists in the use of an oscillating motor or tipping device into which part of the hard water flows until filled, when the arrangement "tips" over by gravity, discharging the contents, and at the same time, by this action, causing "spoons" to dip into the lime and soda ash reagent—also stirred by the motion of the tipper— and discharge a small amount to the raw water as it is violently agitated by falling from the tipper into a small enclosed tank leading down to the main softening plant below. The action is also very powerful since, for example, with a softening plant of 5000 gal. of water per hr., the tipper holds about 500 lb. of water.

An interesting recent Boby softening plant for steam generation and general industrial use, of 16,000 gal. per hr. capacity, is at the Welbeck Colliery of the New Hucknall Colliery Co., Ltd., Nottinghamshire. The local raw water available from springs and wells is of very bad quality, and the plant installed by Messrs. William Boby & Co., Ltd., consists of a lime and soda ash softener, closed pressure sand filters, and an Azed Base Exchange plant to give zero hardness, followed by deaeration with live steam and preheating with exhaust steam. The lime and soda ash plant, shown in Fig. 1, has a vertical reaction tank 52 ft. high and 18 ft., 6 in., dia., and the partially clear water after sludge separation flows by gravity to a battery of three closed pressure sand filters shown, while Fig. 2 is a close-up photograph of this part of the installation. The Base Exchange plant is a single large cylinder with all the necessary valves and pipe connections, having a total capacity of 135,000 gal. of water between regeneration and a maximum duty of 16,000 gal. of zero hardness per hr.

Another recent Boby installation for boiler plant work is at Synthetic Ammonia and Nitrates, Ltd., Billingham-on-Tees (of Imperial Chemical Industries, Ltd.), for dealing with the new International Combustion super pressure, forged steel drum boiler plant of light forged drum boilers, each of 269,000

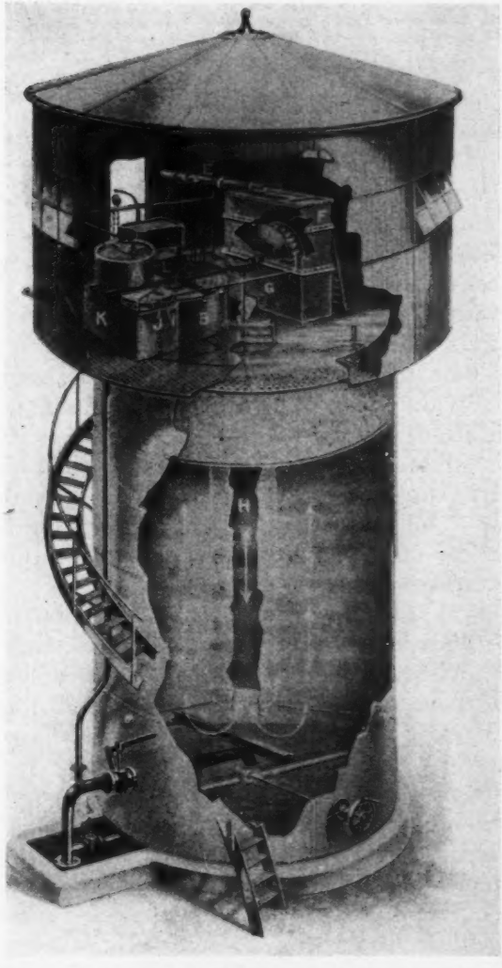


Fig. 5—Kennicott standard "k" type of Lime and Soda Ash Softening Plant

lb. normal evaporation per hr., operating at 800 lb. pressure, fired with Lopulco pulverized fuel. For this purpose, no hardness or alkalinity can be allowed in the water, so that an Azed Base Exchange plant is used to give zero hardness, followed by neutralization of the liberated sodium bicarbonate with acid, this being a method now attracting much attention in the United States, using phosphoric acid.

Further, with regard to Boby Azed Base Exchange

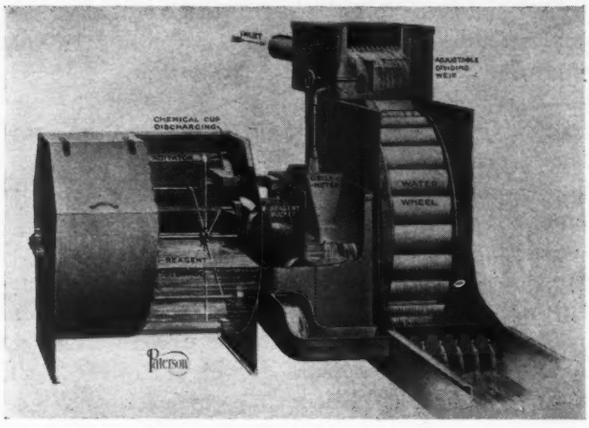


Fig. 6—Osilameter Chemical Feed Gear (by-pass type) used in connection with Paterson Lime and Soda Ash Softening Plant

water softening plants, Fig. 3 is a photograph of an installation at the Bowater Paper Mills, Ltd., Gravesend, Kent, typical of the standard industrial plant, showing the closed cylinder with the necessary pipes and valves for hard water, soft water and salt solution, and drain discharge for the spent brine after regeneration.

Messrs. The Kennicott Water Softener Co., Ltd., Wolverhampton, manufacture the Kennicott lime and soda ash plant, Base Exchange equipment using their Base Exchange material known as Kenzelite, and a wide range of water filtration and general purification plants, including feed water heaters, sand filters, storage water heaters, special instantaneous heaters using exhaust or live steam, the "Kennicott-Bundy" oil separator, Kennicott-Griscom-Russel heater for oil fuel, drinking water evaporation sets and deaerators.

Typical of the latest Kennicott practice in Great Britain is a number of installations, such as at the Radcliffe, Padiham and Kearsley Power Stations of the Lancashire Electric Power Co., Ltd., and at the Barrow Paper Mills Co., Ltd., Barrow-in-Furness.

This consists in the removal of the temporary hardness by lime, using sulphate of alumina as a coagulent, and then treatment with Kenzelite Base Exchange material to give zero hardness water with a negligible degree of alkalinity, the plant at Barrow being illustrated in Fig. 4.

With regard to the Kennicott reagent feed gear for lime and soda ash plant, typical is the "k" type shown in Fig. 5. In this arrangement the hard water flows into a hard water box and discharges through an adjustable slot over a water wheel, and the main volume falls out of the bottom of the water wheel casing into the top of a main downtake pipe in the center of the main reaction tank or cylinder of the plant. This water wheel drives all the agitator and other gear required, and for proportioning the lime and soda ash reagent a small proportion of the hard water is by-passed to a "dividing box" and from here by way of an adjustable slide to a "regulating tank." The slide is set so that the amount of water delivered to the regulating tank fills it in a definite number of hours, while also in the tank is a float connecting over pulleys to a weir in the reagent tank. As the regulating tank fills, the weir in the reagent tank is lowered at exactly the same rate, and the reagent from the weir is delivered into the top of the downtake pipe along with the main bulk of hard water. That is, the amount of reagent added is always in proportion to the flow of the hard water, no matter how this varies. Notable also in the Kennicott standard lime and soda ash plants is the revolving sludge gear at the bottom of the cylinder, while the filter at the top of the main tank may be wood, wool or sand.

Messrs. The Paterson Engineering Co., Ltd., London, are specialists on water purification, whose activities cover town water supply sterilization, purification and filtration, both by rapid gravity sand filters and closed pressure sand filters—in each case including compressed air cleaning, the "Chlornome" apparatus for the automatic and continuous addition of a measured trace of chlorine gas to water, oil elimination plant, Paterson lime and soda ash softening plant with Osilameter feed gear for the reagents, and Basex Base Exchange material for zero hardness water.

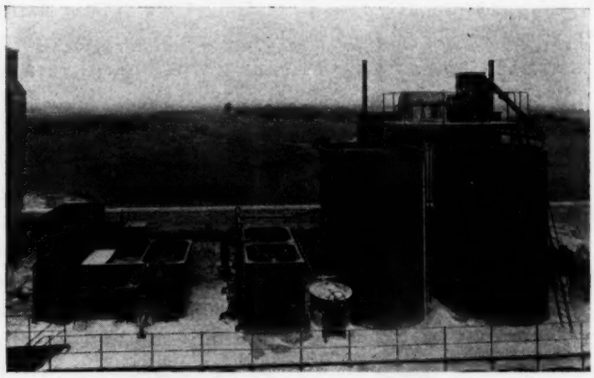


Fig. 7—Paterson Water Softening Plant installed at Messrs. Edward Lloyd, Ltd., the largest paper mill in Great Britain

In Fig. 6 is given an illustration of the Osilameter feed gear by-pass type for the lime and soda ash reagent. In this arrangement the entering hard water flows through a weir, which has a vertical dividing plate removable at will by means of a valve

handle so as to divide the flow of the water into two parts. In normal circumstances something like eighty per cent of the water flows through a large wheel which drives the mechanism and passes to the central drop tube of the plant, while the other twenty per cent actuates the Osilameter feed gear, which is essentially an arrangement of cups forming the spokes of a wheel, so that these cups are dipped into the reagent contained in a suitable tank, lifted up and then poured into twenty per cent of the hard water which flows around, while being thoroughly mixed, and is then added to the main bulk. The whole arrangement, of course, in any case, works in proportion to the demand, as stated, but if the hardness varies, all that is necessary is to adjust, by the wheel valve, the central dividing plates so as to alter the ratio between the two volumes of water and give a corresponding increase or decrease in the amount of reagent added.

A typical Paterson softening plant in the industrial field is illustrated in Fig. 7, being an installation at the establishment of Messrs. Edward Lloyd, Ltd., Sittingbourne, Kent, the largest paper mill in Great Britain, with sixteen paper machines turning out 2200 tons of paper a week. This comprises a Paterson lime and soda ash softening plant with two vertical cylindrical tanks and an oil elimination plant, shown on the left, so that the raw water can be heated by the exhausts of steam engines and every trace of oil afterwards removed.

Since the importance of water softening for locomotives is now being realized in the United States as well as Great Britain, Australia and other countries, two recent Paterson lime and soda ash plants are of interest. One is at Pretoria for the South African Railways and Harbour Board, with a capacity of 200,000 lb. of water per hr. and a cylindrical reaction tank 24 ft. high and 24 ft. dia., built to suit the space available. The other is in England, at the Annesley Locomotive Depot, Nottingham,

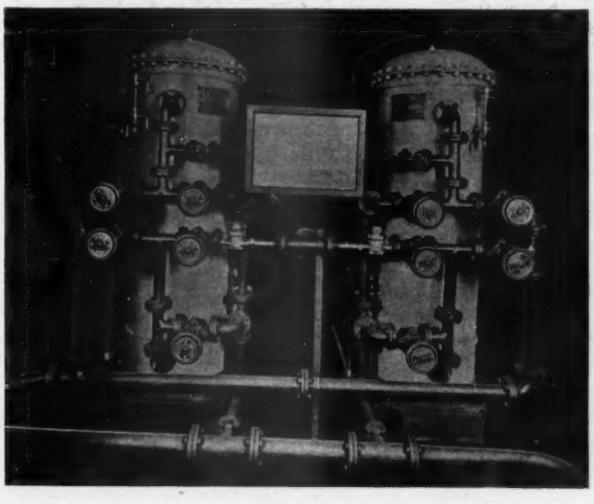


Fig. 8—Basex Zero Hardness Softening Plant installed on S. S. Caronia of the Cunard line.

London, and North Eastern Railway Company, with a vertical tank 37 ft. high and 18 ft. dia., for dealing with very difficult water 38.5 deg. total hardness and a high percentage of difficult magnesium salts, so that 5½ hr. settling has to be allowed.

The Paterson Base Exchange plant, using their

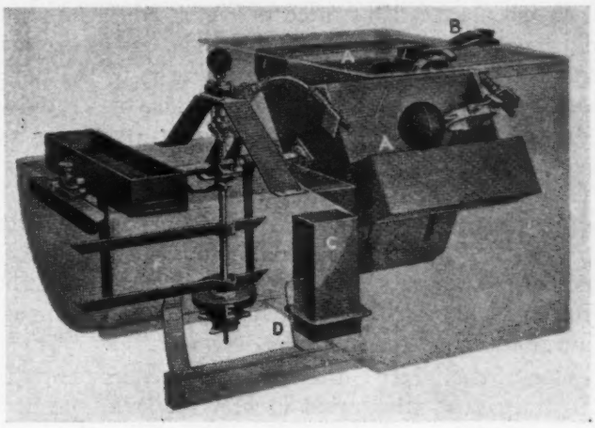


Fig. 9—Reagent Feed Gear for Lime and Soda Ash Plant of the Lassen-Hjort design

product Basex is on the usual lines, and highly interesting is the application to the Cunard steamships. Thus, for example, the S.S. Carmania, S.S. Caronia, and S.S. Mauretania were first fitted, softening the make-up water for the boilers to zero hardness. For the Mauretania the installation is two Basex units, each 2 ft., 6 in. dia., with the usual brine preparing tank and steam jet elevator, and one 3 ft., 6 in. dia. pressure filter, provided with steam jet air injector and steam valve for the agitation of the filtering medium. The capacity of the plant is 1400 gal. of zero hardness water per hr., with a total duty of 11,200 gal. between regeneration by means of salt solution, which only requires about 20 min. Because of the cramped conditions it is impossible to obtain a photograph of this installation, but Fig. 8 is the very similar plant on the S.S. Caronia, being two Basex units 2 ft., 9 in. dia., as seen, with all the pipe connections and valves, and one 2 ft., 6 in. dia. pressure filter, being 560 gal. per hr. and 4500 gal. between regeneration.

The dual principle of using Base Exchange plant in series is illustrated by a Paterson plant just installed on the Cunard liner Berengaria, in which the raw water is reduced to 5 deg. hardness by lime treatment, with a tank 9 ft. high and 9 ft. deep, filtered through two 6 ft. dia. sand filters, and reduced to zero hardness in a Basex plant 3800 gal. per hr. capacity. Finally, it is highly interesting to note that the Chloronome apparatus is now beginning to be widely used in power station practice for the sterilization of cooling water to prevent non-conducting organic growths on the condenser tubes.

Messrs. United Water Softeners, Ltd., of London,

manufacture the Lassen-Hjort lime and soda ash softening plant, the well-known Permutit Base Exchange material and equipment, known in the United States as Zeolite, and much equipment for the filtration, sterilization and general treatment of water, including rapid gravity and closed sand filters.

The reagent gear for the Lassen-Hjort lime and soda ash plant is illustrated in Fig. 9, consisting of a plug valve device (E) in the lime and soda ash container (F), the raw water flowing in by way of a locking gear (B) and filling one end of a double compartment tippler (A), which then overturns by gravity and discharges the contents downwards at (D) to the main reaction tank with outlet (C), while the other compartment commences to fill with raw water. At the same time the valve (E) opens momentarily and allows a measured portion of the lime and soda ash, also stirred up by paddles, to pass out at the same time as the raw water.

One of the latest United Water Softeners plants in Great Britain, illustrated in Fig. 10, is at the new Hams Hall Power Station of the City of Birmingham, the first section of which, 60,000 kw., was officially opened on the 6th of November last. This plant, which is planned for an ultimate capacity of 210,000 kw., deals with 12,000 gal. of boiler feed water per hr. supplied by the City of Birmingham Water Department at Whitacre, having an average total hardness of 15.4 deg. (grains per gal). In order to give a water absolutely free from any trace of scale-forming constituent, the principle adopted is the use, in series, of a lime and soda ash water softening plant, closed pressure sand filtration, and a Permutit base exchange plant to give zero hardness. The lime and soda ash plant of the Lassen-Hjort design has a very large vertical tank, 36 ft. high and 20 ft. dia., with continuous sludge agitation and circulation in the reaction tank, while the reagents used average 0.70 lb. of lime and 0.5 lb. soda ash per 1000 gal., reducing from 15.4 deg. to 5.0 deg. total hardness.

For filtration of the almost clear water two 8 ft. dia. pressure sand filters are used, and the Permutit plant consists of three standard cylindrical softeners, housed in the same building as the sand filters, capable of reducing 432,000 gal. of 5 deg. hardness water to 0 deg. hardness per regeneration. For regeneration the salt required is 2.0 lb. per 1000 gal; that is, 864 lb. per regeneration.

Normally the feed water used for the five boilers, each of 190,000 lb. per hr. normal evaporation and 228,000 lb. overload operating at 375 lb. pressure and 710 deg. fahr. superheated steam temperature, is 50 per cent condensate and 50 per cent zero hardness water from the above plant, containing only a very small amount of mineral salts in solution.

Some of the notable features of this installation include continuous sludge agitation and circulation in the reaction tank to increase the efficiency of the reactions between the hard water and the reagents, as well as the precipitation of the calcium carbonate. Also the regeneration of the Permutit by means of salt solution is carried out in the two-stage system, part of the old brine being employed for the first stage of succeeding regeneration, followed by a lesser volume of fresh brine.

Another of the most notable Permutit industrial installations in Great Britain is at the new Coventry and Wolverhampton works of Messrs. Courtaulds, Ltd., artificial silk manufacturers, while further as regards Lassen-Hjort lime and soda ash plants, Lever Bros., Ltd., at Port Sunlight, have eight plants totalling 2,000,000 gal. of water per day capacity.

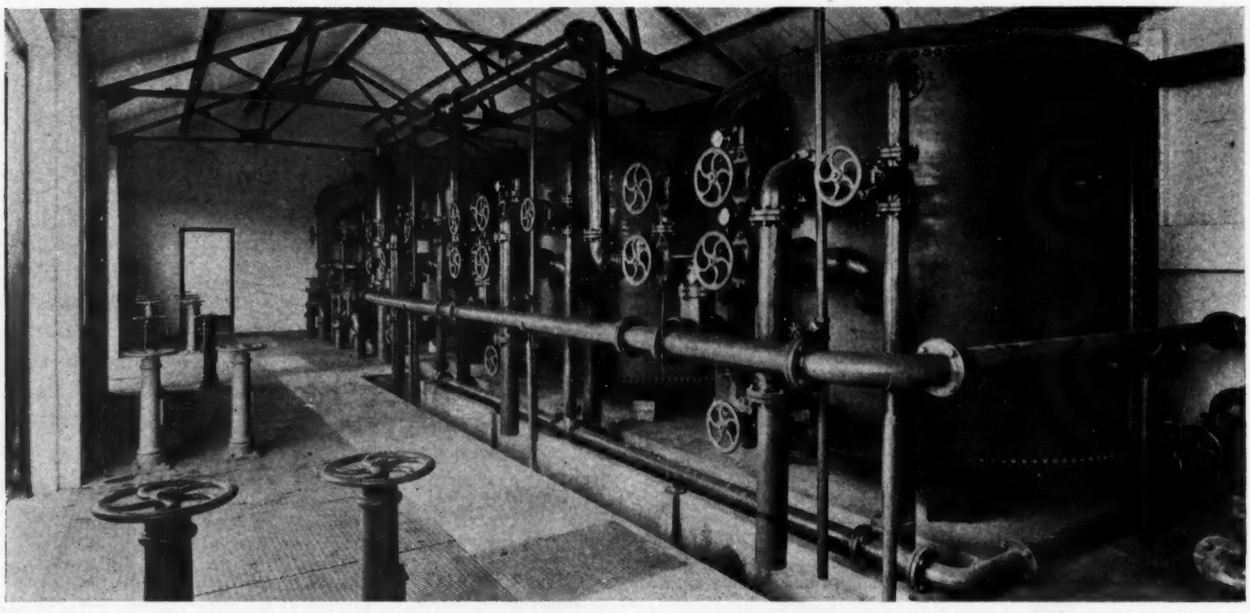


Fig. 10—Permutit Base Exchange Water Softening Plant at the Hams Hall Power Station

Atmospheric Air

By Wm. L. DeBaufre
International Combustion Engineering Corporation

Air is not only essential to our existence but also serves industry in many vital ways. Mr. DeBaufre, a recognized physicist, tells of the constituents of air, their various uses and their physical properties, all of which will be of interest to the combustion engineer because an intimate knowledge of these things is a requisite to his theoretical background. Other articles of this general character will be written by Mr. DeBaufre for subsequent issues of COMBUSTION.

THE composition of dry atmospheric air at the surface of the earth is given by the International Critical Tables as

Nitrogen	78.03	per cent by volume
Oxygen	20.99	" " " "
Argon	0.94	" " " "
Carbon Dioxide	0.03	" " " "
Hydrogen	0.01	" " " "
Neon	0.00123	" " " "
Helium	0.0004	" " " "
Krypton	0.00005	" " " "
Xenon	0.000006	" " " "

Of the dry gases in atmospheric air, oxygen is of most importance to the combustion engineer because it is this element which supports combustion by combining with the carbon, hydrogen and sulphur of coal and other fuels. The oxygen amounts to 20.99 per cent by volume, or 23.19 per cent by weight, so that about 3.3 tons of inert gases must be handled for every ton of oxygen supplied for combustion. The inert gases can be separated from oxygen by liquefying and rectifying the air at a temperature about 300 degrees below zero on the fahrenheit temperature scale; but this process is not sufficiently economical for producing oxygen for ordinary combustion purposes under steam boilers. A large industry has been built upon this process to supply oxygen compressed in cylinders for cutting and welding. It is undoubtedly only a question of time before this process will be utilized for supplying oxygen to enrich the air used in certain metallurgical and other industrial processes where the benefits of higher quality product and greater capacity of furnace justify the cost at which oxygen can be produced.

Nitrogen separated from atmospheric air by the same process of liquefaction and rectification is employed in the production of fertilizers by the cyanamid process. Argon is separated from atmospheric air by an additional step in the rectification process to use as an inert gas in incandescent lamps in order to enable the filament to be operated at higher temperatures than permissible in lamps which have simply been exhausted of atmospheric air. The use of argon greatly increases the light obtained from a given amount of electrical energy.

The carbon dioxide in atmospheric air must be removed as an impurity before the air is cooled to separate the other constituents by rectification; otherwise, the operation of the process would soon be stopped by accumulation of solid carbon dioxide. This material is the "dry ice" which has recently come into use for preserving ice cream in paper cartons; but the quantity of carbon dioxide in atmospheric air is so small that it is not economical to separate it for the production of "dry ice." Hydrogen also can be obtained more cheaply from other sources than by separating it from atmospheric air.

Neon from atmospheric air is used in incandescent signs which give the familiar red glow. Helium to inflate airships is not obtained from atmospheric air but from certain natural gases containing much larger percentages of this element. Krypton and Xenon are not separated from air for commercial purposes.

The composition of the dry gases of the atmosphere is remarkably constant over the earth's surface at ordinary elevations. At great elevations, the proportions of the dry gases change from those given above. This is of importance to the meteorologist but rarely to the engineer whose operations are usually confined to the surface of the earth. Even in aviation, altitudes are seldom reached where the change in composition of the atmosphere is important.

There is a component of atmospheric air, however, which is variable at the surface of the earth. This variable is the proportion of water vapor contained in atmospheric air. Some textile industries can be conducted only under certain conditions of atmospheric moisture. The operation of the blast furnace for producing pig iron is greatly affected by changes in the moisture content of the air blown into the furnace. Even the operation of boiler furnaces is affected by the amount of water vapor in the atmosphere and the efficiency of a steam generating unit depends upon the moisture content of the air supplied for combustion.

The moisture content of atmospheric air is often expressed in terms of relative humidity. A relative humidity of 70 per cent means that there is present in the atmosphere 70 per cent of the maximum quan-

tity of water vapor which the air can hold at the existing temperature. This maximum quantity varies with the temperature and can be found by reference to tables of the properties of steam such as prepared by Goodenough. At 70 deg. fahr. for example, the density of saturated steam is 0.001153 lb. per cu. ft. and this is the maximum weight of water vapor a cubic foot of space can hold. With 70 per cent relative humidity, each cubic foot of the atmosphere contains 0.001153 × 0.70 = 0.000807 lb. of water vapor as superheated steam.

When the temperature of the atmosphere drops, the superheated steam therein approaches the saturated condition. For 70 per cent humidity at 70 deg. fahr., the saturated condition is reached at a temperature of 59.2 deg. fahr. as may be seen by reference to steam tables for the temperature corresponding to a saturated steam density of 0.000807 lb. per cu. ft. Any further cooling of the atmosphere would produce condensation of a portion of the water vapor, so that 59.2 deg. fahr. is the "dew point" of air with 70 per cent relative humidity at 70 deg. fahr.

Warming of the atmosphere lowers the relative humidity, although the moisture content remains the same. Thus at 80 deg. fahr., steam tables show the density of saturated steam to be 0.001580 lb. per cu. ft. For the same moisture content as in air at 70 deg. fahr. with 70 per cent relative humidity, the relative humidity at 80 deg. fahr. is thus 0.000807/0.001580 = 51 per cent only.

Relative humidity is generally measured by "wet and dry bulb thermometers" rather than by dew point apparatus. When the bulb of a thermometer is kept covered by a moist wick, the indication of the thermometer is lowered below that of a dry bulb thermometer which indicates the true air temperature. The wet bulb temperature lies between the true air temperature and the dew point. Various relations have been worked out for calculating the relative humidity and the moisture content of air from the wet and dry bulb indications and the barometric pressure.

It is sometimes thought that the more moisture contained in the atmosphere, the denser it must be; but the reverse is true because the moisture displaces dry gases of greater density. Thus, the density of the dry gases contained in the atmosphere is 0.07490 lb. per cu. ft. at 70 deg. fahr., and under the normal atmospheric pressure of 29.92 inches of mercury. For a relative humidity of 70 per cent at 70 deg. fahr., the pressure of the water vapor is 0.70 × 0.7386 = 0.52 inch of mercury, where 0.7386 inch of mercury is the pressure of saturated steam at 70 deg. fahr. Due to the presence of the water vapor, the pressure of the dry gases is reduced to 29.92 — 0.52 = 29.40 inches of mercury. The density of the dry gases is reduced in proportion to the reduction in pressure to 0.07490 × 29.40/29.92 = 0.07360 lb. per cu. ft. The density of the moist air is therefore 0.07360 + 0.000807 = 0.0744 lb. per cu. ft., which is thus less than the density of dry air at the same pressure and temperature.

Matthew Murray *and* "Steam Hall"

MATTHEW MURRAY was one of the most remarkable engineers of all time. He was born, so far as can be ascertained, at Newcastle-on-Tyne in 1765, and in his youth was apprenticed as a mechanic or blacksmith in Stockton-on-Tees. He later joined the firm of Fenton, Wood & Lister and erected on a site near Camp Fields, Water Lane, Holbeck, a large circular workshop, which ever since has been known as the "Round Foundry," and is still in existence. Many British engineers who achieved fame in their profession served their time as apprentices at the Round Foundry.

While with this firm, Matthew Murray effected many improvements in both steam engines and boilers. In 1799 he invested a self-acting damper for boilers, operated by a rack and pinion by the steam pressure. So far as can be determined this was the first automatic damper control in the history of the world; the same principle was used afterwards by William Brunton in connection with his famous mechanical stoker in 1819.

About the year 1800 Murray built a house close to his engineering works, which was entirely heated by steam pipes and was known ever afterwards as "Steam Hall." This is believed to be the first example in the history of the world of the use of steam for heating a private house.

Murray gained recognition as an expert in many different fields of engineering, and particularly hydraulic work, in which connection today Leeds is the chief engineering center in the United Kingdom, based entirely on the pioneer work of Matthew Murray. He also carried out some important pioneer work on mechanical stoking which exerted a considerable influence on the early history of this branch of steam generation.

Plans are now being considered for the erection of a suitable memorial to him in Leeds. A highly interesting publication on the subject is "Matthew Murray, Pioneer Engineer," by E. Kilburn Scott, published by the latter privately at 84 Kingsway, London, W.C.2, and being sold to aid the funds for the Matthew Murray Memorial..

UNUSUAL STORIES FROM THE FIELD

This page will be devoted to stories of unusual happenings which test the reserve resources of men and equipment

A Winter Morning Load Pick-Up

10,000 Pounds a Minute

By A. R. MUMFORD,
New York Steam Corporation, New York

The operation of a steam plant is not mere routine. Hidden away in performance records and daily reports there is romance galore, stories of unusual demands placed upon equipment and personnel—demands which must be met by men who are schooled to act quickly and correctly and whose ability and training equip them to do the right thing at the right time, instinctively. Engineers and operators are invited to contribute to this page, stories of unusual plant performance or of operating emergencies and how they were met.

IT was five o'clock on a cold December morning.

I stood with my back to the end wall of the firing aisle at Kips Bay Station with the vague shapes of four tremendous boilers towering above me.

The aisle was well lighted, but the brilliant illumination of the four control boards with their polished brass and glittering glass shone so bright that the other areas of the firing floor seemed dim by contrast.

A man stepped into the flood of light in front of one of these panels and stood for a moment reading each gage in turn. His attitude of alertness created an air of expectancy—something was about to happen.

The uppermost gage commanded more of his attention than the others. Presently he touched a control button near the center of the panel and then he quickly scanned other gages and touched other buttons with a quiet deliberateness that bespoke his mastery of the situation.

Leaving the first control panel, he visited each of the others in turn, unhurriedly performing the same operations, with now and then a step through the shadows to a point where his face was bathed in the brilliant yellow light of the furnace flames as he peered through one of the observation doors.

At frequent intervals that morning gages were read and control buttons were pressed as the rate of steam generation was kept in pace with the ever increasing rate of steam demand. At six o'clock the operator stepped to the telephone and spoke his report into the transmitter, "Full load."

What had happened? What changes had been brought about by this reading of gages and pressing of buttons? I examined the charts. The rate of steam delivery from each boiler unit is recorded by a red ink line drawn on the chart of the flow meter. At five o'clock these lines had indicated a total load of 960,000 pounds of steam per hour on all four of the boilers. At six o'clock the readings of the four meters totalled over 1,580,000 pounds. I had seen one man, except for the occasional visits of his chief, increase the generation of steam in those four boilers over 600,000 pounds per hour —a load increase of over 10,000 pounds of steam per minute.

I had watched this one man sending his electrical orders over tenuous nerves of copper to gigantic fans sixty feet above me, to whirring coal feeders just over my head and to the rumbling pulverizer mills forty feet below.

In my mind's eye I compared the achievement of this lone operator with the efforts of six sweating firemen whom I had once watched and whose work I had tested, in a low, grimy boiler room at Washington. I recalled that I had been able to see their glistening, reeking faces only when one of the men flung open a furnace door to feed a paltry fifty or hundred pounds of coal. Those six men, by hand firing, had brought twelve boilers each rated at one hundred horsepower from bank to full load in one hour. By their back breaking labor they had succeeded in increasing the steam output in one hour about as much as this lone operator at the control panels had averaged each minute for a full hour.

Man released by machinery from drudgery to higher social standards; offices warmed to welcome in comfort the workers entering from the chill streets, a giant boiler giving a tithe of its energy to operate itself, one man doing the work of 100—this is progress.

How *to* Estimate *the* Loss *of* Heat Due *to* Radiation *from a* Boiler Setting

By B. J. Cross

Combustion Engineering Corporation, New York

THE loss of heat due to radiation from the outside surfaces of a boiler and setting cannot be accurately measured. It can, however, be estimated with a fair degree of accuracy, or at least a value can be set which it is doubtful that this loss will exceed. As the chief purpose of the determination of boiler losses is to obtain the boiler efficiency by difference, maximum values should be assigned to all losses, the accuracy of the measurement of which might be questioned.

Having given the temperature of the radiating surface, its area and the temperature of the surface to which it is losing heat, the heat lost by radiation may be computed by the well known Stefan and Boltzmann law. This law states that the interchange of heat by radiation between two surfaces is in proportion to the difference of the fourth power of their absolute temperatures. In its fundamental form this law is expressed by the following equation:
Q = heat lost − B.t.u. per hr. $= 17.23 \times 10^{-10} \times E [(T_1)^4 - (T_2)^4] \times A$ in which T_1 and T_2 represent the absolute temperature of the two surfaces, A the area of the surface losing heat and E a constant dependent upon the character of the surface.

As the fourth power of the absolute temperature (deg. fahr. + 460)^4 involves rather large figures, the equation may be simplified by dividing these temperatures by 100 and making a corresponding change in the combined constant.

$$Q = C \times \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)\right] \times A$$

The value of the constant C will vary with the type of surface. Its value for characteristic surfaces is as follows:

Unfinished iron surfaces	.163
Glossy black paint	.140
Flat black paint	.164
Unpainted asbestos	.160
Aluminum paint	.110
*Bare bricks	.160

*The value of C for bare brick surfaces has not been established. A probable value .16 has been assigned.

The curves on page 49 have been prepared from the Stefan and Boltzmann equation. The heat radiated, B.t.u. per sq. ft., may be determined from these curves when the temperature of the radiating surface and the temperature of the surrounding surfaces are known. Locate the temperature of the hot surface in the bottom horizontal scale and trace vertically upward to the curve for the cooler surface. From this intersection trace horizontally to the proper coefficient line and from this intersection trace vertically upward to the top scale which gives the loss in B.t.u. per hr. per sq. ft. of surface. This procedure is indicated by the broken lines, for a case when the surface temperature is 175 deg. fahr., the room temperature 70 deg. fahr. and a coefficient C = .16.

The value thus obtained accounts only for radiated heat. The heat lost by convection at the temperature of surfaces of a boiler setting will be about 50 per cent of the heat radiated. This is a high value for vertical surfaces and probably low for horizontal surfaces. As over 80 per cent of the surface of a boiler setting is vertical the 50 per cent correction for convection will give a maximum value for this loss.

A sample computation of the radiation and convection loss for a 1000 hp. boiler is given in the following table.

Surface	Area Sq. ft.	Temp. deg.fahr.	B.t.u. per sq. ft. per hr.	Total B.t.u. per hr.
Boiler Top	425	210	195	82,875
Left Side	885	185	150	132,750
Right Side	885	185	150	132,750
Rear	625	175	135	84,375
Front	600	180	145	87,000
Hopper	500	190	160	80,000
8 Access Doors	24	225	225	5,400
6 Manhole Covers	10	325	500	5,000

Total radiation—B.t.u. per hr	610,150
Convection allowance	305,075
Total loss—B.t.u. per hr	915,225
Heat input to furnace at rating = 4,200,000 B.t.u. per hr.	
Per cent loss at 100 per cent rating	2.2

All of the losses heretofore described in this series of articles have been computed in B.t.u. per lb. of fuel fired. As radiation losses are computed in total hourly losses in B.t.u., in order to express them as B.t.u. per lb. coal, it is necessary to know approximately the hourly coal fired. Under good operating conditions the loss of heat from the setting will vary only slightly with rating. The per cent loss will therefore vary inversely with rating. Once the total hourly loss has been computed it can be calculated to per cent loss for 100 per cent rating. The per cent loss at any rating may then be easily determined.

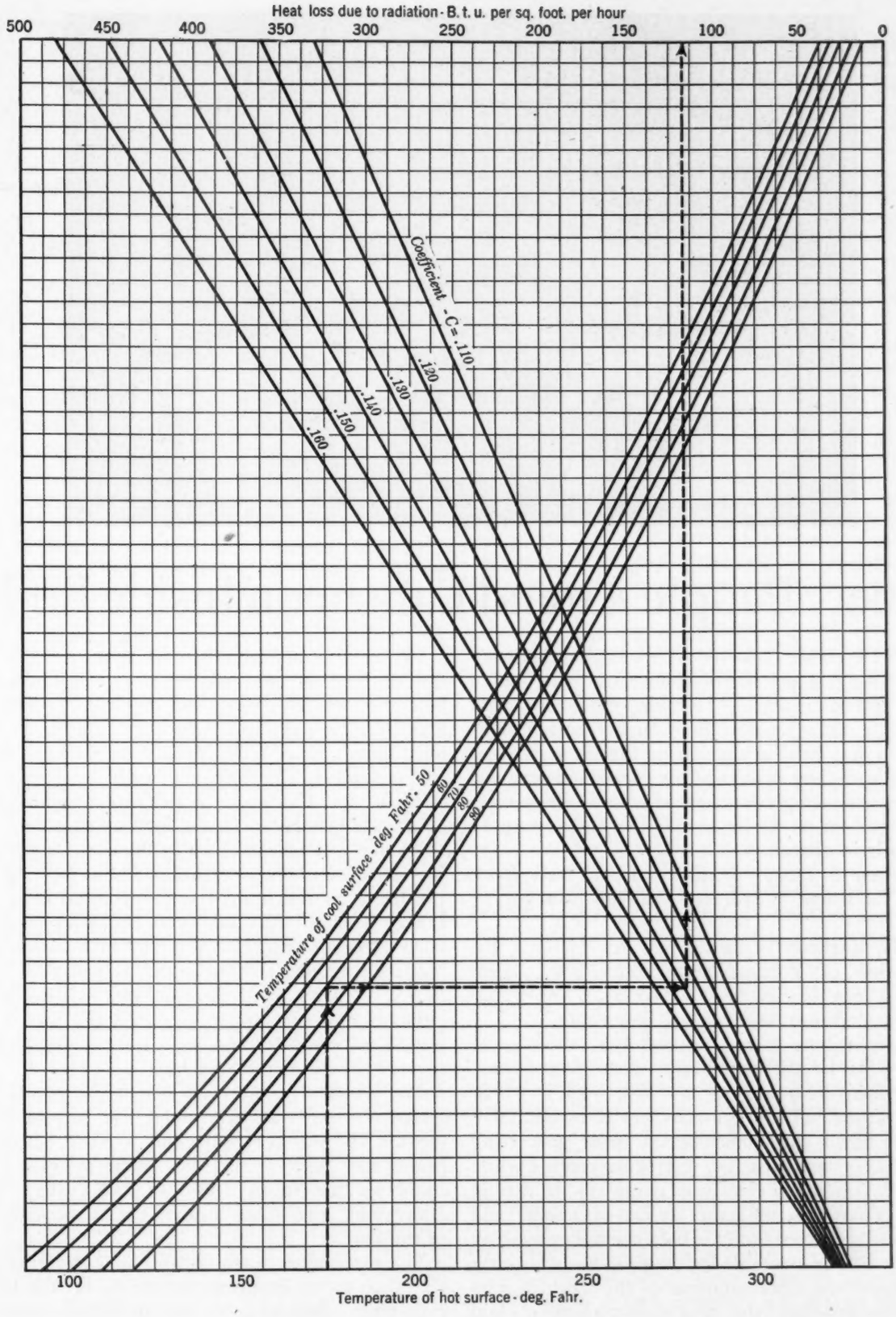


CHART FOR DETERMINING LOSS OF HEAT DUE TO RADIATION FROM A BOILER SETTING

No. 6 of a series of charts for the graphical solution of steam plant problems

Ninety People Attend Luncheon Inside Boiler

ON December 2, the New York Edison Company gave a novel luncheon to those who had a part in the work of installing three new steam generating units in the East River Station. The luncheon was held in the last of the three units to be completed, and as soon as the guests had departed the huge wooden platform on which the diners were seated was set on fire to season the boiler prior to placing it in operation.

Matthew S. Sloan, president of The New York Edison Company, in addressing the luncheon guests, said:

"This luncheon is being held to celebrate the completion of a remarkable achievement, never equalled in this city and, so far as I know, unequalled, certainly unsurpassed, anywhere.

"Between June 1 and December 1, three great boilers—the largest ever built—were erected here. Two of them are now in service. The third, in which we are seated, will be put into service immediately after we finish this luncheon. A great generating unit, 215,000 hp. capacity, was being erected while the work on the boilers was going on. It was in service at part capacity before the end of October, and as soon as this third boiler is fired the full generating capacity will be available for the people of this city.

"You are the representatives of the workers who made this possible—the men who planned it, laid out the program for the work and carried it through to successful completion. To you, and to the two thousand other men who worked here on this job, and to the thousands of others in mines and factories and mills who had some part in it, I extend congratulations and thanks.

"When the engineers of our companies laid out this six months' program, we were told it couldn't be carried out. We were told no such job had ever been done, and certainly this one could not be done in so short a time. Well, it *was* done. The first boiler was scheduled to be fired on October 15. It was fired on that date. The second boiler was scheduled to be fired on November 7. It was fired on that date. The third one was scheduled to be fired on December 1. It was built and ready on that date, but we held over the firing so we could have this celebration here today. You did this job—you and your people. I wish everyone who had any part in it, directly or indirectly, could be here with us today. I know they'd all get a thrill of pride, just as I do, at the immensity of the undertaking and the fact it succeeded on schedule, and with only a minimum of overtime work at the very last."

The wooden platform on which the guests were seated was built ten feet above the bottom of the furnace, and was 43 ft. 6 in. long by 23 ft. 6 in. wide. Eighty-five feet above the platform the diners could see the steam drums of the boiler. These dimensions give some idea of the tremendous size of the unit.

The three units, each capable of generating over 1,000,000 lb. of steam per hr. are by far the largest ever built. The 215,000 hp. turbo-generator, for which these units will supply steam, will generate sufficient electricity to have carried the entire lighting load of the United States in 1906.

The steam generating units were furnished and installed by Combustion Engineering Corporation, and the turbo-generator by General Electric Co.

NEWS

National Management Congress to be Outstanding Event

THE National Management Congress will be held at the Stevens Hotel, Chicago, March 3 to 5, 1930.

The theme of the program for this meeting has been expressed by one of Industry's leaders as "Organizing for Permanent Prosperity." The Congress will present a picture of modern industrial practices covering management, production and distribution, greater than ever before attempted, according to plans now outlined. The meeting will be a cooperative one consisting of members of the following societies: Society of Industrial Engineers, American Society of Mechanical Engineers, American Management Association, National Association of Cost Accountants.

Eight sessions have been planned, beginning Monday, March 3rd, and sufficient diversification of subjects has been included to cover major industrial endeavors. There will be sessions on waste elimination; distribution; mechanization in the administrative field; budgeting; plant maintenance; wage incentive plans; industrial managership training; and management and production control. Able authorities in each field will present papers, and ample opportunity will be afforded for detailed discussion by members and others participating.

Practical application of management's part in building and maintaining Industry will be in full evidence during the three-day meeting. Executives and plant managers will find plenty of good material in the papers to justify active participation, and assist in helping to promote a better understanding of this important part of Industrial engineering.

During the same week, and in the same building, the National Industrial Equipment Exposition will be held, portraying a vivid cross section of equipment and services to be found in the management field. Five classifications will cover the various sections of the Exposition:

1st—Materials Handling Equipment,
2nd—Plant Construction Materials,
3rd—Power Transmission,
4th—Management Production Control,
5th—Factory Operation Requisites.

The exhibits located in the exhibition hall of the Stevens Hotel will offer every facility for inspecting the latest industrial methods and equipment.

Gas Sales Increase

New York, Dec. 14.

AN increase of 12 per cent in gas sales for October, 1929 over the corresponding month of the preceding year, is indicated by reports of the American Gas Association from companies representing approximately 80 per cent of the industry, according to Paul Ryan, statistician of the association. On October 31, the customers of these companies aggregated 9,607,000, an increase of 2.2 per cent over the same date a year ago.

For the first ten months of 1929, these companies reported gas sales of 361 billion cubic feet, representing an increase of 9.7 per cent for the period. Revenues from gas sales aggregated $342,335,000, an increase of 4.4 per cent over the first ten months of 1928. This relatively slower rate of increase in revenues is the result in part of rate reductions inaugurated in various sections of the country during the period, and in part due to the more rapid increase in gas sales for industrial-commercial uses, where because of large volume consumption coupled with steady all year round use, or high load factor, the companies are able to profitably handle this class of business at lower than average rates.

The amount of coke oven gas purchased from coke and steel companies for public distribution by the reporting companies also increased materially during the ten month period, being nearly 30 per cent above the preceding year, while coke oven gas produced by the utilities themselves increased 28 per cent during the same period.

The Lincoln Electric Company, Cleveland, Ohio, manufacturers of "Stable-Arc" Welders and "Linc-Weld" Motors, announces the recent appointment of two new district sales representatives.

R. B. Tuhey has been advanced to District Representative at Indianapolis, Indiana, with offices at 517 Peoples Bank Building.

S. H. Taylor has been promoted to the position of District Representative at Los Angeles, California, with headquarters at 812 Mateo Street

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General Refractories Company, Philadelphia, Pa., announces the following three appointments as exclusive dealer representatives in their respective territories: Paxson Taggart Co., Luzerne and D Streets, Philadelphia; Bison Builders Supply Co., 1345 Genesee Street, Buffalo; and Harris Pump & Supply Co., 319 First Avenue, Pittsburgh.

John Van Brunt, vice president of Combustion Engineering Corporation, New York, has been appointed chairman of the Fuels Division of the American Society of Mechanical Engineers for 1930.

New Refractory Developed for Baffles and Door Linings

TESTS of a new refractory material suitable for boiler baffles and furnace door linings have recently been conducted at the Mellon Institute of Industrial Research, Pittsburgh, under the direction of Stuart M. Phelps.

The new refractory is obtained by mixing Lumnite, a building cement, with Plibrico, a high temperature cement, and where low temperatures are encountered it was demonstrated that the serviceability of Plibrico is increased by the addition of Lumnite.

In this investigation the pyrometer cone equivalent test gave Plibrico the highest value, and Lumnite the lowest. With mixtures of the two materials, it was shown that as the percentage of Lumnite was increased, the pyrometric cone equivalent was lowered, but the mechanical strength increased up to the fusing point of the mixture. Tests made on four inch cubes with one face exposed to heat showed satisfactory strength under load up to a temperature of 2500 deg. fahr.

Mr. Phelps stated in his report, "It will be noted from these data that the higher the percentage of Lumnite, the stronger the cube at low temperatures. As the temperature increases, however, the straight Plibrico reaches the same strength as the mixture and, of course, is more refractory."

Ceramic Fuels Investigation

Trial of Stoker Firing to Inaugurate Extensive Study

The Ohio Department of Welfare, the U. S. Bureau of Mines, the Whiting Corporation and the Ohio Ceramic Industries Association are cooperating with the Engineering Experiment Station of Ohio State University, on an investigation of the use of fuels in firing brick, tile, and other clay products in round, downdraft, periodic kilns. The Experimental Clay Products Plant at Roseville will be the laboratory. Plans for the investigation are practically complete.

Fuels of all kinds, including various grades of coal, gas and probably oil are eventually to be studied for use in ceramic plants. This study will involve efficiency of fuels, convenience and effect on the quality of the product.

A particularly noteworthy feature of the study of the use of coal is the trial of stoker firing. A forced draft stoker, designed especially for the purpose, will be used. The investigation of stoker firing will require several months, perhaps a year. It is expected that introducing the hot gases into the kiln under pressure will give a more uniform heat distribution than is possible when the heat flow is dependent on natural draft alone. Two kilns are to be used and an arrangement of dampers will permit these kilns to be fired one at a time, or both together.

The study will be under the general direction of P. Nichols, Supervising Fuel Engineer of the U. S. Bureau of Mines, and G. A. Bole of the Engineering Experiment Station, Ohio State University.

Metal Frog Serves Insull as Mechanical Messenger

"Oscar" Obeys Nine Commands of Utilities Executive

SAMUEL INSULL, Chicago Utilities executive, has on his office desk a single object—a little green frog fondly dubbed Oscar, says the Associated Press.

It is a metal frog, with a gaping mouth. If the visitor makes as if to mop his brow, Mr. Insull inquires: "Is it warm in here?" and commands: "Oscar, make it cooler!" The heat is promptly shut off in the radiator. Other commands bring similar compliance, Oscar obeying nine different orders.

The principle, of course, is the same one employed by science in the so-called mechanical man, samples of which have been displayed widely of late. Oscar has a micro-electric cell in his bosom.

Combustion Engineering Corporation, New York, has announced the opening of a new district office at 1411 Fourth Ave., Seattle, Wash. George M. Bechtel, formerly sales engineer at the company's Los Angeles office, has been appointed manager of the new Seattle office.

Paul A. Schoellkopf, chairman of the Buffalo, Niagara & Eastern Power Corporation, has been elected president of the Niagara Hudson Power Corporation to succeed Ray P. Stevens, who resigned. Mr. Stevens is president of Stevens & Wood, Inc., engineers, and the American Electric Power Corporation.

Francis R. Wadleigh, consulting, mining and fuel engineer, and Ernest L. Bailey, mining engineer, announce their association as consultants and engineers in coal mining and fuel utilization, with offices at No. 1 Broadway, New York.

The Chain Belt Company, Milwaukee, Wisc., announces the appointment of the following new distributors in the Southeast:

The Bailey-Lebby Co., Charleston, S. C., The Georgia Supply Co., Savannah, Ga., and Jacksonville, Fla., Harry P. Leu Co., Orlando, Fla., and the J. M. Tull Rubber and Supply Co., Atlanta, Ga.

NEW CATALOGS AND BULLETINS

Any of the following literature will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Arc Welding of Pipe Lines

The general acceptance of arc-welded pipe line construction and the rapid growth of the use of this process insures a keen interest in any new literature on the subject. A new bulletin by J. F. Lincoln, president, The Lincoln Electric Company discusses the identification of Lincoln Arc Welding with the construction of more than 3000 miles of pipe lines. Numerous illustrations are included to show methods employed and details of the work. 12 pages, 8½ x 11—The Lincoln Electric Company, Cleveland, Ohio.

Boilers

Bulletin B V M-1 presents the VM Type Combustion Engineering Boiler which is of the bent tube, three drum type and is designed especially for limited space conditions, particularly where the head room is low. The front drum of this boiler is located so that it is not fully submerged. This arrangement permits some steam liberation to take place in the front drum—a feature of value in producing dry steam. Typical setting arrangements and tables of dimensions are included. 8 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Ave., New York.

Corrosion Resistant Alloys

T. H. Nelson, Consultant Metallurgist, has prepared a booklet "Corrosion Resistant Alloys in General Fabrication." The advantages of Chromium Iron Alloys and Nickel Chromium are outlined in considerable detail and many analyses and test data are presented to support the claims for these materials. Numerous photographs show tanks and containers made of these alloys and used in chemical and heat transfer work. 24 pages and cover, 8½ x 11—Downington Iron Works, Downington, Pa.

Differential Pressure Valve

The new Swartwout Type SLP Differential Pressure Valve is a refinement of the Former Type SV valve and is offered as the latest development in the control of excess pressures in connection with boiler feed water regulation. This valve will maintain a constant low differential pressure under ordinary ratings, but will gradually increase the differential pressure to any desired amount up to full pump discharge pressure, as the load increases and approaches its peak. Bulletin S-19 describing this new valve is well illustrated and includes two charts in colors. 8 pages, 8½ x 11—The Swartwout Company, 18511 Euclid Ave., Cleveland, Ohio.

Feed Water Regulator

The Campbell Feed Water Regulator is described in a folder which shows the details of construction and principle of operation. The Regulator is simple in operation, contains no moving parts and requires no adjusting after the initial installation. A partial list of installations is included together with a table of dimensions, weights and prices. 4 pages, 8½ x 11—Atlas Valve Company, 282 South Street, Newark, N. J.

Flexible Coupling

The L-R Flexible Coupling is strong, simple and silent. It consists of two coupling halves with jaws and a resilient center spider of rubber, fibre or leather depending upon the type of service. The metal jaws do not touch and the non-metallic spider serves to insulate the two halves. The coupling provides for misalignment, end play and starting torque. 4 pages, 3½ x 6¼—Lovejoy Tool Works, 319 West Ohio Street, Chicago, Ill.

Graphic Instruments

Several new bulletins are available describing Esterline-Angus graphic instruments. Bulletin 929 pertains to graphic speed records of steam and hydraulic turbine operation. Bulletin 1029 describes methods for continuous inspection of various manufacturing processes. A wide range of instruments is offered for the graphic recording of various factors and bulletins devoted to each application, may be secured. 4 pages each, 8½ x 11—The Esterline-Angus Company, Indianapolis, Ind.

High Pressure Fittings

Cast Steel Fittings for use with high steam pressures and temperatures are discussed in a recent report of tests made to determine the variation in tensile strength of steel fittings at various temperatures within the range of 75 deg. to 1000 deg. fahr. Two charts are reproduced to show the variation in ultimate strength and yield point over the temperature range. 4 pages, 8½ x 11—Pittsburgh Piping & Equipment Co., Pittsburgh, Pa.

High Temperature Cement

The uses of Hytempite, a high temperature refractory cement are outlined in Bulletin No. 252. Hytempite air sets at normal temperature and provides a strong, permanent bond for new refractory work, or, for hot or cold patching of old firebrick work by either the gun or paddle method. Numerous illustrations suggest a wide range of work in which Hytempite may be used. 8 pages, 8½ x 11—Quigley Furnace Specialties Co., 26 Cortlandt Street, New York.

Protective Boiler Coatings

New Bulletin 1181 gives recommendations regarding the application of Apexior protective coatings to new water-tube boilers, waterwalls and economizers. It is recommended that mill scale be removed from the internal surfaces of the boiler before it is erected, that the boiler be boiled out for the removal of grease and oil after it is completely erected and finally, that Apexior protective coating be applied before the unit is placed in final operation. These processes are described in detail. 4 pages and cover, 8½ x 11—The Dampney Corporation of America, Hyde Park, Boston, Mass.

Refractory Lined Hoppers

A new bulletin No. 15, presents Hahn Sectional Cast Iron Hoppers lined with high temperature refactories. These lined hoppers are recommended for receiving hot or quenched ashes and clinkers from grates, stokers, pulverized fuel firing and industrial furnaces. 6 pages, 8½ x 11—Hahn Engineering Company, Division of Lancaster Iron Works, Lancaster, Pa.

Smoke Charts

A request on business stationery will bring to any engineer a set of Ringlemann smoke charts with instructions for their use in measuring smoke density. A table showing the common causes of smoky combustion and the principle remedies is also included together with general data pertaining to the correct design of furnaces. Plibrico Jointless Firebrick Co., 1836 Kingsbury Street, Chicago, Ill.

Soot Blowers

The application of Diamond Soot Blowers to return tubular boilers and internally fired boilers is covered by a new folder entitled "You Ought to Operate Your Return Tubular Boilers More Economically." Numerous illustrations are shown and the savings effected by proper soot removal are discussed. Two flue gas temperature charts are reproduced to show the lower exit gas temperatures due to the installation of soot blowers. 8 pages, 8½ x 11—Diamond Power Specialty Corporation, Detroit, Mich.

Stokers

The Westinghouse Link Grate Multiple Retort Stoker is illustrated and described in a new catalog No. 1864. This stoker combines the effective underfeed principle of conventional design with the combustion characteristics of an overfeed area and the fuel and refuse conveying ability of an undulating Link-Grate system. Numerous illustrations show details of design and application arrangements. 12 pages and cover, 8½ x 11—Westinghouse Electric and Manufacturing Co., South Philadelphia Works, Philadelphia.

Valves

Pratt & Cady iron and bronze valves, cocks and Reading cast steel valves and fittings, are covered in a new catalog No. 330. Information is presented on the care of valves and the application of floor stand valves, chain wheel operated valves and motor operated valves. Tables of dimensions are given and a section of useful engineering information is included. 264 pages with covers, 6 x 9—The Reading Steel Casting Co., Bridgeport, Conn.

Welded Piping

In the December issue of COMBUSTION, we reviewed "Design Standards for Oxweld Steel and Wrought Iron Piping," a hand book intended for the use of engineers in designing welded piping systems in accordance with recognized practice. A supplementary hand book, "Fabrication of Welded Piping Designs" has since been issued for the use of executives, foremen and welders, to enable them to apply successfully the fundamental designs described in the former booklet. 88 pages, 6 x 9—The Linde Air Products Co., 30 East 42nd St., New York.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured through In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Gaseous Combustion at High Pressures

By WILLIAM A. BONE, DUDLEY M. NEWITT AND DONALD T. A. TOWNEND

WILLIAM A. BONE is professor and head of Chemical Technology in the Imperial College of Science and Technology at London. Mr. Newitt and Mr. Townend have been associated with him on tests which have been conducted since 1906, with the exception of the war period, at the Imperial College at London.

The experimental studies presented in this book consist chiefly of hydrogen-air, carbonic oxide-air and methane-air explosions at various initial pressures between three atmospheres and two hundred atmospheres.

In these experiments, the data relative to the activation of nitrogen in carbonic oxide-air are fully set forth and discussed. These data offer a striking example of how high pressure can reveal new phenomena in gaseous explosions.

In Chapter 15, a new view is outlined respecting the function of steam in promoting the combustion of carbonic acid. In succeeding chapters, such subjects as the distribution of the energy and the condition of the medium at the moment of maximum pressure, the calculation of the mean maximum temperature and the heat capacities of the product in gaseous explosions at high pressures are discussed in the light of the experimental results. The experiments on hydrocarbon combustion at high initial pressures are fully described.

The authors have developed special types of bombs and pressure gages for this work and give a very complete outline of the apparatus that has been used in the preparation, storage and compression of the gases.

Most of this information has been published in either Proceedings or Philosophical Transactions of the Royal Society, but the above book collects this material together in complete form for the use of people who are interested in this line of work.

The results published in the book are of extreme interest and help to people interested in catalytic chemistry and will be of great assistance in developing this branch of chemistry. They will also be of assistance to engineers who are interested in the design of internal combustion engines.

The authors have compared their results with those that have been conducted by other experimenters and this feature makes the book a valuable adjunct to the library of chemists and engineers who are interested in this line of work.

The appendix contains a complete bibliography, a summary of the principal data relating to compressibilities of gases and a description of the new Bone-Newitt gas analysis apparatus now employed at the laboratory in which the experiments were conducted.

The book is well illustrated and includes many charts, diagrams and tables. It is bound in cloth covers, 6½ by 10, and contains approximately 400 pages. The price is $15.00.

Industrial Economics

By DEXTER S. KIMBALL

THIS book presents, in a simple and very readable style, the economic background of industry from the earliest days of organized business up to the present. A discriminating selection of the really important events and trends in economic history enables the author to cover this period fairly comprehensively in a few chapters.

A chapter on basic industrial principles traces the rapid development of business from the inception of the idea of the transfer of skill from men to machines, which idea marked the beginning of mass production and specialization of labor.

After providing this brief and thoroughly interesting background, the book takes on a very practical aspect. Chapters are devoted to the fundamentals of production considered from both organization and economic standpoints; to standardization and specialization; and to the elimination of waste through the scientific study of variety in number and sizes of products manufactured.

Later chapters discuss the principles of organization as they apply to the major functions of manufacturing business generally. A particularly interesting feature of this part of the book is the description of the various types of organization, namely: military or line, functional, and line and staff, and the accompanying charts showing typical examples of these organization set-ups.

Those who wish to be better informed in the economics of business and the trends in business management will find this book both interesting reading and of very practical value.

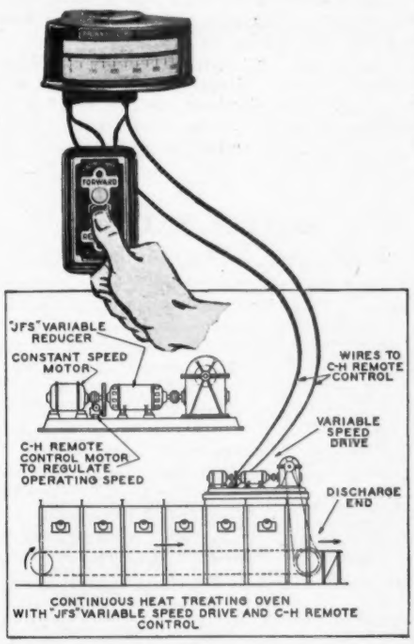
It is bound in cloth covers, 6¼ by 9¼, and contains 312 pages. The price is $3.00.

• NEW EQUIPMENT •

Push Button Control for Operating Speeds

BY pushing either the forward or reverse button of the new electrical control for the JFS speed changer, the speed of conveyors or other machines can be increased or decreased for any desired capacity, without the operator leaving the control panel.

The JFS variable speed reducer, made by Stephens-Adamson Mfg. Co., Aurora, Ill., is offered as a practicable drive unit for increasing or decreasing operating speeds. Many plants have increased production noticeably by being able to speed up certain machines at different times during the day.


FORWARD
"JFS" VARIABLE REDUCER
CONSTANT SPEED MOTOR
WIRES TO C-H REMOTE CONTROL
VARIABLE SPEED DRIVE
C-H REMOTE CONTROL MOTOR TO REGULATE OPERATING SPEED
DISCHARGE END
CONTINUOUS HEAT TREATING OVEN WITH "JFS" VARIABLE SPEED DRIVE AND C-H REMOTE CONTROL

Ordinarily, the speed is regulated by means of a hand wheel on the JFS unit. Where the drive is accessible this method is satisfactory enough, but when the drive is overhead or located in a crowded space the control becomes difficult.

In several recent installations, the problem has been solved by using an electrical push button control on the speed changer. The usual control hand wheel is replaced with a spur gear driven forward or backward by means of a compact control motor mounted on the base. The push button box can be located at any distance from the drive and the speed is increased or decreased by simply pressing the proper button.

As long as the "increase" button is pressed the unit continues to increase its output speed. When the desired speed is reached the button is released and the rotation remains constant until a new speed is wanted.

Approximately one minute is required to change speed from one extreme to the other

Where the push buttons are located at some distance from the machine, an electrical tachometer is used, because of its quick and accurate registration, to show the exact speed being delivered by the speed changer.

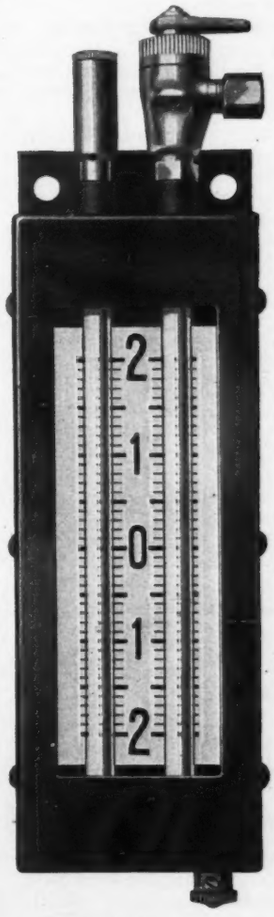
A New U-Draft Gage

To meet modern requirements for U-Gages, the Ellison U-Draft Gage, embodying new features of gage construction, has been designed by Lewis M. Ellison, Chicago.

It has wide application for direct reading of air or gas pressures, minus or plus, or differential. It is available in the convenient ranges of 4, 6, 8, 12 and 16 in. calibrated in inches of water, using red oil; and 5, 8, 10, 15 and 20 in. of mercury (or pounds per square inch) using mercury.

It is rigidly enclosed in a compact dust proof case and is provided with fittings and sliding scale for zero adjustment. The Ellison U-Draft Gage employs colored oil as the indicating liquid which evaporates but slightly and does not discolor the glass tube. The red oil in large bore tube over a white scale with prominent figures gives easy visibility and quick vision of operating condition prevailing.

The casing is of Armco iron stamping in black finish, firmly constructed and resistant to corrosion. A removable front cover is



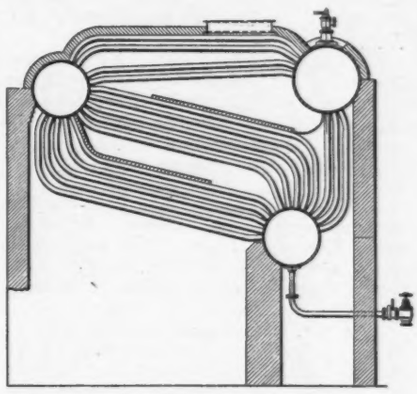
provided with cork gasket to insure dust tightness. All screw holes in the casing are brass bushed. Plate glass 3/16 in. thick provides a window with excellent visibility of the scale and tube.

The liquid for gages reading in inches of water is a mineral oil, specific gravity .834 at 60 deg. fahr., 38 deg. Baume, colored red. The advantages of using oil instead of water are that the oil has practically no evaporation, eliminates coating of the glass surface, and has a constant movement with unvarying capillary attraction. In low temperatures where the oil congeals, low gravity kerosene, colored red, will be furnished with correction factor.

For range scales calibrated in inches of mercury or pounds per square inch, brass nipples are replaced by steel suitable to the use of mercury as the indicating fluid.

A Boiler for Low Head Room

THE VM-Type, Combustion Engineering Boiler is a bent-tube boiler designed especially for limited space conditions, particularly where the head room is low.



Various setting arrangements can be made so as to permit the use of the method of firing best suited to the application conditions and load requirements. The height may be adapted to hand firing, stoker firing or to firing by means of pulverized fuel, oil or gas.

VM-type boilers are usually offered for the following maximum ratings:

Working Pressures	Ratings in Per Cent
Up to 5 lb. per sq. in.....	100
5 to 14 lb. per sq. in.....	150
15 lb. and over.....	200

Of especial advantage in the operation of a boiler of this type is the location of the front drum so that it is not fully submerged. This arrangement causes some steam liberation to take place in the front drum—a feature of real value in producing dry steam.

A further advantage is the ideal circulation in the boiler produced by the arrangement of the tubes between the drums. The two lower rows of tubes, between the upper drums, show in the setting drawing carry water in circulation. The upper tubes, between the same drums, carry steam, thus providing a circulation similar to that in the well-known cross-drum boiler.

The VM-type boiler can be arranged for either horizontal baffling as shown, or for a combination of horizontal and vertical baffling, with the gases traveling transverse to the tubes.

When the combination horizontal and vertical baffling is used, a very satisfactory arrangement for the installation of a superheater, is provided.

VM-type boilers are simple in design, substantial in structure and efficient in performance.

PATENTS

Recently granted, and of Interest to our Readers.

Printed copies of Patents are furnished by the Patent Office at 10 cents each. Address the Commissioner of Patents, Washington, D. C.

UNITED STATES PATENTS

Issued November 12, 1929

1,734,983. Steam Boiler. Herman B. Smith, Plainfield, N. J., assignor to the Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Jan. 21, 1926.

1,735,345. Steam Boiler. William H. Winslow, Chicago, Ill., assignor to George W. Dulany, Jr., Chicago, Ill. Filed Feb. 14, 1927.

1,735,464. Boiler. Ernest C. Keithley, Detroit, Mich., assignor to The Superheater Company, New York, N. Y. Filed Sept. 30, 1927.

Issued November 19, 1929

1,736,243. Apparatus for Feeding and Metering Pulverulent Material. Ervin G. Bailey, Cleveland Heights, Ohio, assignor, by mesne assignments, to Fuller Lehigh Company, a Corporation of Delaware. Filed Apr. 22, 1925. Renewed Apr. 5, 1929.

1,736,411. Steam Generating Installation. Franz Losel, Brunn, Czechoslovakia. Filed Aug. 3, 1923, and in Germany Aug. 5, 1922.

1,736,462. Steam Generator. Mark Robinson, Waterloo, near Liverpool, England. Filed Nov. 5, 1926.

1,736,564. Stoker. Willard J. Woodcock, Brooklyn, N. Y. Filed Nov. 6, 1926.

1,736,565. Automatic Stoker. Willard Jay Woodcock, Brooklyn, N. Y. Filed Jan. 31, 1927.

1,736,610. Method of Manufacturing High-Pressure Boilers. Stephan Loffler, Charlottenburg, Germany. Filed Mar. 28, 1925, and in Germany Apr. 11, 1924.

1,736,612. Steam Turbine. Alf Lysholm, Stockholm, Sweden, assignor to Aktiebolaget Ljungstroms Angturbin, Stockholm, Sweden, a Joint Stock Company of Sweden. Filed Apr. 26, 1928, and in Sweden May 2, 1927.

1,736,752. Furnace Regulation. Arthur R. Smith Schenectady, N. Y., assignor, by mesne assignments, to Bailey Meter Company, a Corporation of Delaware. Filed Jan. 20, 1926.

1,736,753. Furnace Regulation. Arthur R. Smith Schenectady, N. Y., assignor, by mesne assignments, to Bailey Meter Company, a Corporation of Delaware. Filed Jan. 19, 1927. Renewed Apr. 10, 1929.

Issued November 26, 1929

1,736,791. Motor Operated Valve Mechanism. Emil A. Ileman, New York, N. Y., assignor, by mesne assignments, to Consolidated Ashcroft Hancock Company, Inc., New York, N. Y., a Corporation of Delaware. Filed Sept. 18, 1926.

1,736,800. Composition for Removing Boiler Scale. Hans Rathje, Buffalo, N. Y. Filed Jan. 12, 1928.

1,736,882. Furnace Wall Construction. George P. Jackson, Flushing, N. Y., assignor to International Combustion Engineering Corporation, New York, N. Y., a Corporation of Delaware. Filed Oct. 2, 1925.

1,736,898. Boiler. George W. Bach, Erie, Pa., assignor to Union Iron Works, Erie, Pa., a Corporation of Pennsylvania. Filed Sept. 25, 1925.

1,736,903. Pulverized Fuel Burner. Otto de Lorenzi, Maplewood, N. J., assignor to International Combustion Engineering Corporation, New York, N. Y., a Corporation of Delaware. Filed Sept. 30, 1926.

1,736,909. Method of Making Refractories. Roberts L. Frink, Lancaster, Ohio. Filed Sept. 18, 1926, renewed Oct. 24, 1928.

1,736,929. Art of Burning Finely Divided Fuel. Edwin Lundgren, Frederick, Md., assignor to Combustion Engineering Corporation, a Corporation of New York. Filed Nov. 19, 1924.

1,736,990. Oil Burner. Le Roy Wilcox, Detroit, Mich., assignor to Cope-Swift Company, Inc., a Corporation of Michigan. Filed Nov. 18, 1927.

1,737,003. Sectional Furnace. James Doherty, Chicago, Ill.; Ella Maud Doherty and James Russell Doherty executors of said James Doherty, deceased. Filed Mar. 21, 1923.

1,737,213. Apparatus for Automatically Controlling the Feed Water of Steam Boilers. Louis Maurice Bernon, London, England, assignor of one-half to Robert James Walker, Leicester, England. Filed Mar. 17, 1927, and in Great Britain Apr. 13, 1926.

1,737,232. Combustion Tube for Oil Burners. William M. Griffin, Fort Wayne, Ind., assignor to The Wayne Home Equipment Company, Baltimore, Md., a Corporation of Maryland. Filed Sept. 24, 1928.

1,737,239. Refractory Arch Brick. Raleigh J. Himmelright, New Rochelle, N. Y., assignor to General Refractories Company, Philadelphia, Pa., a Corporation of Pennsylvania. Filed Mar. 21, 1928.

1,737,385. Steam Boiler. John A. Pilcher and John A. Doarnberger, Roanoke, Va. Filed Apr. 24, 1925.

1,737,444. Hammer Mill. John Gilmore Wilson, Paoli, Pa. Filed Jan. 4, 1928.

1,737,448. Method of Working for the Cleaning of Boiler Feeding Water. Moritz Bauer, Stuttgart, Germany. Filed July 22, 1925.

1,737,517. Steam Turbine. James Judson Provost, York, Pa. Filed Sept. 26, 1928.

1,737,529. Valve for Fuel Storage Tanks. John Hyde Viele, Elmira, N. Y. Filed May 5, 1927.

Issued December 3, 1929

1,737,591. Device for Blowing Boilers. Alfred G. Kernin, Mosinee, Wisc., assignor to Mosinee Paper Mills Company, Mosinee, Wisc., a Corporation of Wisconsin. Filed Apr. 2, 1928.

1,737,681. Retort for Carbonizing Bituminous Fuels. Josef Plassmann, Duisburg, Germany, assignor to Chemisch-Technische Gesellschaft m.b.H., Duisburg, Germany. Filed June 14, 1926, and in Germany, June 30, 1925.

1,737,756. Metallic Baffle. Isaac Harter, Dongan Hills, N. Y., assignor to the Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed June 19, 1925, and renewed Oct. 11, 1929.

1,737,791. Electric Power-Generating System. Hans Geisen, Berlin-Charlottenburg, Germany, assignor to Siemens-Schuckertwerke Gesellschaft mit beschrankter Haftung, Siemensstadt, near Berlin, Germany, a Corporation of Germany. Filed Feb. 17, 1926, and in Germany Feb. 17, 1925.

1,737,809. Boiler and Superheater having Replaceable Tubes. Thomas B. Stillman, South Orange, N. J., assignor to the Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Apr. 21, 1925.

1,737,931. Coal Pulverizer. Frank G. Lugrin, Moose Jaw, Saskatchewan, Canada. Filed Jan. 5, 1928.

1,737,988. Boiler. Benjamin B. Whittam, Elizabeth, N. J., assignor to the Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Mar. 29, 1927.

1,738,455. Steam Condenser. Arthur R. Smith, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. Filed Dec. 10, 1927.

1,738,507. Closed Feed System for Steam Power Plants. James George Weir, Cathcart, Glasgow, Scotland, assignor to G. & J. Weir, Limited, Glasgow, Scotland. Filed Aug. 23, 1927, and in Great Britain Oct. 8, 1926.

BRITISH PATENTS

Accepted October 8, 1929

319,626. Improvements in or relating to Guide Plates or Retarders for the Tubes or Coils of Heat Exchangers, Exhaust Silencers of the like. Samuel Newbigin Kent, of 16, Henderson Road, Wandsworth Common, London, S.W. 18, and Torben Christian Billetop, of Springfield, Lesbury Road, Heaton, Newcastle-on-Tyne.

309,439. Improvements in or relating to Steam Generator Furnaces. Foster Wheeler Limited, of Aldwych House, Aldwych, London, W.C.2.

319,223. Improvements in or relating to Rotary Retorts for the Distillation or Heat Treatment of Carbonaceous Materials. Harald Nielsen, of 73, Hayes Road, Bromley, County of Kent, England, and Bryan Laing, of York Mansion, Petty France, Westminster, County of London.

319,453. Improvements in Feed Water Heaters. Sebastian Otto Alfred Fiedler, of 30, Rue de Mogador, Paris, France.

319,464. Improvements relating to the Carbonisation of Coal. Alfred Smallwood and John Fallon, both of Cornwall Road, Smethwick, County of Stafford.

319,476. Improvements in and relating to Steam Condensers. Eugen Haber, of No. 18, Droysenstrasse, Berlin-Charlottenburg, Germany.

319,550. Improvements in and connected with Superheaters. Babcock & Wilcox Limited, of Babcock House, Farringdon Street, London, E.C.4.

319,567. Improvements relating to the Drying of Steam or Vapours Under Pressure. Arthur Valder, of "Fairmead," East Boldon, Durham.

319,573. Improvements relating to Water Circulating Devices for Steam Boilers. George Johnston Ferguson, of 50, Wellington Street, Glasgow.

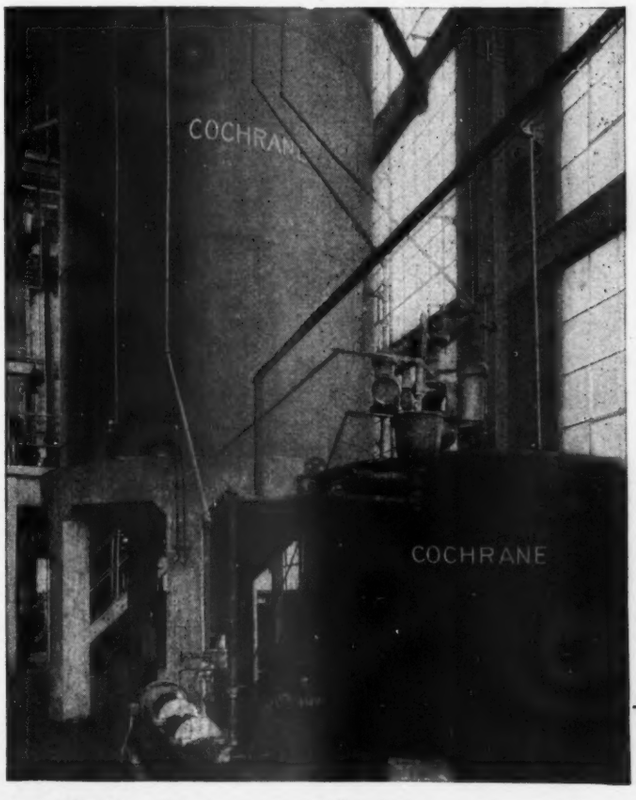
319,583. Improvements in and relating to Apparatus for Conveying Pulverized Fuel to Furnaces. Alfred John Elderton, of "La Casita," Shepherds Lane, Dartford, Kent.

(*Continued on page 58*)

STEAM USERS PREFER
COCHRANE
HOT PROCESS

THE more experience that steam plant owners have with the several water conditioning systems, the more they favor the COCHRANE HOT PROCESS LIME-SODA SOFTENER as best for boilers. This fact is well illustrated by the following list of 21 nationally known concerns which have purchased some 88 Cochrane Softeners, of an aggregate capacity of over 3,000,000 gal. per hr.

NAME OF USER	NUMBER OF INSTALLATIONS	GAL. PER HOUR TOTAL CAPACITIES
Standard Oil Company	17	415,000
Diamond Alkali Co.	1	60,000
Magnolia Oil Co.	1	70,000
Texas Gulf Sulphur Company	2	420,000
Carnegie Steel Company	2	250,000
Bethlehem Steel Company	11	214,100
Weirton Steel Company	2	196,000
Jones & Laughlin Steel Co.	1	180,000
Solvay Process Co. including Semet Solvay	8	177,000
Shell Co. including Roxana Petroleum Corporation	15	172,080
Penn Public Service Company	2	120,000
Texas Company	5	108,500
Mid-Continent Petroleum Co.	3	100,400
Pittsburgh Plate Glass Company	6	85,000
Narragansett Electric Ltg. Co.	1	80,000
Tennessee Coal, Iron & R. R. Co.	3	67,890
Kansas City Power & Light Co.	2	62,000
Granite City Steel Company	1	60,000
Republic Iron & Steel Company	2	57,600
University of Michigan	2	50,000
Commercial Solvent Company	1	50,000



Engineers who are concerned with the treatment of water for boiler feeding will find a wealth of information in the following issues of the COCHRANE BULLETIN:

IC—678—Obtaining Zero Hardness in Softening Water.

IC—681—Deaerating Heaters for Preventing Oxygen Corrosion.

IC—670—Softening Water for Steam Boilers.

Bulletins sent upon request.

COCHRANE CORPORATION

3160 North 17th Street
PHILADELPHIA, PA.

474

At left—Cochrane Hot Process Softener in a Canning Plant of the H. J. Heinz Co.

Accepted September 19, 1929

(*Continued from page 56*)

295,029. Improvements in or relating to Air-cooled Steam Condensers. Aktiebolaget Ljungströms Angturbin, of Strandvägen 5A, Stockholm, Sweden.

319,094. Improvements in Fuel Bunkers for the Steam Generators of Locomotives, Marine and Stationary Engines and Plant. Beyer Peacock and Company Limited, of Gorton Foundry, Manchester, County of Lancaster, and Robert Harben Whitelegg, of "Woodend," Disley, County of Chesire.

319,097. Improvements in, and relating to, Boiler Furnaces. Atlantic Scalers and Painters, Limited, of 1, Queen Square, Bristol, and Ernest Edward Poole, of 2, The Square, Pill, County of Somerset.

319,108. Improvements relating to Steam Accumulators. John Dawson Troup, of "Te Puanga," Plough Lane, Purley, Surrey.

Accepted September 23, 1929

292,539. Electrically Operated Closing Means for Vertical-chamber Ovens. Bamag-Meguin Aktiengesellschaft, of 10/17, Reuchlinstrasse, Berlin, N.W. 87, Germany.

319,380. Improvements in Steam Boilers. Spencer-Hopwood Limited, and Arthur Lincolne Hitchcock-Spencer, both of Hitchin, Herts.

Accepted September 26, 1929

296,024. Process of Operating Boiler Plants with Several Heat Accumulators. Clemens Kiesselbach, of 58a, Poppelsdorfer Allee, Bonn-on-Rhine, Germany.

300,278. Improvements in or relating to Coke-ovens. Friedrich Totzek, of 24, Salkenbergsweg, Essen-Stoppenberg, Germany, assignee of Heinrich Koppers Aktiengesellschaft, of Postfach, 948, Essen, Germany.

304,743. Improvement in Coking Retort Ovens. The Koppers Company, of 800, Union Trust Building, Pittsburgh, Pa., assignees of Joseph Van Ackeren, of 800, Union Trust Building, Pittsburgh, Pa.

307,494. Improvements in Water Tube Boilers. Fried. Krupp Germaniawerft Aktiengesellschaft, of Kiel Gaarden, Germany.

319,428. Improvements in or relating to Steam Boilers. Unito Pisi, of N.W. Corner 8th and Fitzwater Streets, Philadelphia, Pa.

Accepted October 3, 1929

319,862. Improvements in Apparatus for Removing Dust from Air and other Gases. Frederick Richard Simms, of Percy Buildings, Gresse Street, Rathbone Place, London, W.1, and Bertram Charles Joy, of 55 Yale Court, Honeybourne Road, West Hampstead, N.W.6.

319,864. Improvements in and relating to Machines for Crushing Coke, Coal and other Materials in the form of Lumps. Isaac Henry Pilot, of 25, Cleveland Road, Brighton, Sussex.

319,897. Improvements in or relating to Machines for Grinding Ores, Minerals, Stones and the like. Joseph Richard Broadley, 300, Alexandra Park Road, Wood Green, London, N. 22.

319,930. Improvements in Oil Fuel Burners. Celeste Assirati, and Guiseppe Asserati, both of 28, Pentonville Road, Islington, London, N. 1.

320,008. Improvements in or relating to Boiler Cleaners. Leo John Bayer, and the Bayer Company, both of 1504 S. Grand Blvd., St. Louis, Mo.

Accepted October 8, 1929

320,334. Improvements in or relating to the Forehearths of Glass Melting Furnaces. The British Hartford-Fairmont Syndicate, Limited, of 143, Aridrey House, Ely Place, Holborn, County of London, and Thomas Wardley, of Rockware Avenue, Greenford, County of Middlesex.

Accepted October 9, 1929

320,347. Improvements in or relating to Furnaces. Alfred William Bennis, of Little Hulton Bolton, County of Lancaster.

Accepted October 14, 1929

320,389. Improvements with regard to the Generation and Utilization of Steam. G. & J. Weir, Limited, of Holm Foundry, Cathcart, Glasgow, and James George Weir, of the same address.

320,407. Improvements in and relating to Smoke Consuming Devices for Boiler and Other Furnaces. Arthur Russell Kelly, of The Red House, Quorn, Loughborough, Leicestershire.

Accepted October 16, 1929

320,623. Improvements in or relating to Fuel Combustion Systems for Furnaces or Carbureting Systems for Internal Combustion Engines. Alfred Wallington Field, of 176, Old Road, Clacton-on-sea, Essex.

320,841. Improvements in or relating to Annealing and Heat Treating Furnaces. Arthur Theodore Kathner, of New Cumberland, County of Hancock, W. Va.

320,865. Improvements in or relating to Annealing and Heat Treating Furnaces. Arthur Theodore Kathner, of New Cumberland, County of Hancock, W. Va.

Accepted October 17, 1929

298,651. A Furnace for the Sintering, Burning and Roasting of Substances. Ernst Curt Loesche, of Kaulbachstrasse 60a, Berlin-Lankwitz, Germany.

298,986. Improvements in Steam Generating Plant. Franz Jaschik, of 24, Roonstrasse, Kattowitz, Poland.

320,508. Improvements in or relating to Furnaces for Boilers. The Gas Light and Coke Company, of 84, Horseferry Road, Westminster, London, S.W.1., Percy Gray and William Gordon Adam, both of The Tar and Ammonia Products Works of The Gas Light & Coke Company, Beckton, London, E.

320,525. Waste-Heat Boiler Plant on Forge or other Continuously Burning Fires. Caspar Stubbecke and Heinrich Julius Stubbecke, both of Hachen/Westfalen, Germany.

Accepted October 18, 1929

320,659. Improvements in Hopper and like Door Operating Mechanism. South Metropolitan Gas Company, of 709, Old Kent Road, London, S.E. 15, and Alec Joseph Skinner, of 31, Denbigh Street, London, S.W.1.

Accepted October 21, 1929

320,658. Improvements with Regard to the Generation and Utilization of Steam in Marine Installations. G. & J. Weir, Limited, of Holm Foundry, Cathcart, Glasgow, and James George Weir.

320,669. Improvements in Hot Water Feeding for Locomotive Boilers. Alexander Spencer, of 2, Central Buildings, Westminster, London, S.W.1, and ACFI Limited, of 2, Central Buildings.

320,686. Improvements in or relating to Air Heaters and Gas Heaters. W. Edward Kochs & Company Limited, of 301, Glossop Road, Sheffield, County of York.

Accepted October 22, 1929

320,853. Improvements relating to the Automatic Coke-charging of Gas Generators and the like. Humphreys & Glasgow, Limited, of 38, Victoris Street, City of Westminster, and James Caldwell Stelfox, of the same address.

Accepted October 24, 1929

303,133. Improvements relating to Furnaces for Burning Powdered Coal. Allgemeine Elektricitäts-Gesellschaft, 2-4, Friedrich Karl-Ufer, Berlin, N.W.40, Germany.

320,711. Improvements in Electric Circuit Controls for Electrically Operated Liquid Fuel Burning Apparatus. William Warren Triggs, of Marks & Clerk, 57 & 58, Lincoln's Inn Fields, London, W.C.2.

320,768. Improvements in or relating to Furnaces. George Hirsch, of No. 3, Schwendistrasse, Freiburg, Breisgau, Germany.

320,776. Improvements relating to Grate Bars for Furnaces. James Stanworth, of the Woodlands, Rimington, near Clitheroe, in the County of York.

320,780. An Apparatus to Control the Behavior of Coal or other material while being Carbonized in a Retort, in Order to Facilitate the Discharging of it. William Fraser, 111, Ardeer Square, Stevenston, Ayrshire, British, and William Davidson, 62, Robertson Street, Glasgow, British.

320,788. Improvements relating to the Distillation of Coal in Vertical Retorts. Harold Shewring, of 99, Edenfield Road, Rochdale, County of Lancaster.

Accepted October 28, 1929

320,948. Improvements in or relating to Oil Fuel Burners. Jack Vikruss Mason, of 20, Golders Green Crescent, London, N.W. 11.

Accepted October 31, 1929

303,860. Improvements in and relating to Safety Devices for Steam Power Installations. International General Electric Company, Incorporated, of 120 Broadway, New York, assignees of Allgemeine Elektricitats Gesellschaft, of Friedrich Karl Ufer 2/4, Berlin, N.W., Germany.

305,039. Improvements in and relating to Steam Plants Employing Intermediate Superheating. International General Electric Company, Incorporated, of 120, Broadway, New York, assignees of Allgemeine Elektricitats Gesellschaft, of Friedrich Karl Ufer 2/4, Berlin, N.W., Germany.

307,017. Improvements in and relating to Steam Generators. Aktiengesellschaft Brown, Boveri & Cie., of Baden, Switzerland.

307,421. Improvements in or relating to Stam Boilers. Compagnie des Surchauffeurs, of 3 rue la Boetie, Paris, France.

310,878. Improvements in or relating to Multiple Stage Steam Power Plant. Siemens-Shuckertwerke Aktiengesellschaft, of Berlin-Siemensstadt, Germany.

321,022. Improvements in or relating to Boilers. Lucien Boutin, and Yves Susbielles, both of 24, rue Kervegan, Nantes, France.

321,054. Improvements in Steam Boiler with Superheater. Siegmund Sokal, of 1, Great James Street, Bedford Row, London, W.C. 1.

321,075. Automatic Safety System or Device for Steam Boilers or Generators, Salvador Herrejon Lopez, Accountant, of Avenida Ninos Heroes, 49, Altos, 4, Mexico City, Mexico.